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Maine's Intertidal Habitats

Maine State Planning Office

Executive Department

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November 1985

Maine's Intertidal Habitats

A Planner's Handbook

A Report Prepared for the
Maine State Planning Office
(edited by Robert Deis)

by
Bigelow Laboratory for Ocean Sciences
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Cover Photo. A wide gravel beach on Mount Desert Island.

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PREFACE

Planning Considerations and Coastal Resource Development

Since 1977, as part of Maine's Coastal Program, the State Planning Office has published a series of handbooks to assist private citizens and developers, as well as members of local planning boards and professional planners, with convenient guides to the management of coastal resources.

These handbooks provide the reader with sufficient technical background to communicate successfully with specialized scientists and technicians when considering developments proposed for shoreline and intertidal sites. They also serve as users' guides to specialized maps displaying coastal data. Non-technical language is used as much as possible without diminishing the accuracy of the information.

Development and utilization of the natural resources within Maine's coastal area must and will continue for the benefit of all. Protection of the natural values provided by those resources for future as well as current use is a fundamental public responsibility for decision makers in the present. Decisions affecting the fate of the public interest in coastal resources are being made regularly at the local, state and federal levels of government. Typical situations include local planning board decisions on shoreland and subdivision development proposals, state Board of Environmental Protection decisions on conditions attached to major development proposals under the Site Location Act, and decisions by the U.S. Army Corps of Engineers on permits to construct harbor improvements.

In most cases, development proposals may move forward once assurance is given to regulatory authorities by developers that reasonable care will be taken to protect public environmental values. Protection can usually be achieved by employing construction practices or safeguards shown to prevent or minimize permanent environmental damage, by refraining from known detrimental practices, or by relocating the proposed activity to a more suitable site.

The first step toward assuring that a development will meet the resource protection test is an awareness by both the developer and the regulatory agency of resource values likely to be affected by the proposed activity, so that development plans may be designed to provide the necessary protection.

In the following descriptions of various kinds of intertidal habitats, resource values likely to be affected by development are mentioned. Thus, the reader is alerted to some of the planning considerations associated with particular types of marine geologic environments which may be impacted by various kinds of development activity.

This particular publication, **Maine's Intertidal Habitats: A Planner's Handbook**, is a revision of an earlier report on the ecology of Maine's Intertidal areas by Peter Larsen and Lee Doggett of the Bigelow Laboratory for Ocean Sciences.[1] The original report, addressed to the scientific community, has been edited by environmental writer Robert Deis, to publish a version with the planning community in mind. The text has been augmented with discussion of the potential ecological impacts of development proposed for intertidal areas.

State Planning Office staff principally responsible for this publication are David Keeley, Manager for Maine's Coastal Program, Richard Kelly, who designed the publication, and Harold Kimball, who coordinated the publication process.

[1] Larsen, P.F. and L.F. Doggett. 1981. The Ecology of Maine's Intertidal Habitats. Maine State Planning Office and Bigelow Laboratory for Ocean Sciences.

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FIGURE 1. View along the boulder beach at Roque Bluffs.

INTRODUCTION

Between the limits of high tide and low tide lies an area that is one of the most important and dynamic parts of Maine's complex coastal ecosystem. Its living and non-living resources provide us millions of dollars in commercial gain as well as a great wealth of opportunities for recreational, educational and aesthetic enjoyment. Of necessity, we go to this area to build our piers, wharves and other marine transportation facilities. We also go to dig clams, to harvest mussels and seaweeds, to study interesting ocean creatures, to collect beautiful reminders of seaside trips, and to swim and build sand castles. It is called the "intertidal zone", a unique strip of land found along our coastline where the land and sea meet.

This handbook, developed by Maine's Coastal Program and researchers from the Bigelow Laboratory for Ocean Sciences, has a two-fold purpose: to provide an introduction to the ecology of Maine's intertidal zone; and, to help coastal residents, town planners and developers understand how to use and protect intertidal habitats in ways that will insure long-term productivity and usefulness for generations to come.

For the handbook to be as meaningful as possible, some knowledge of the natural and man-made factors affecting intertidal areas is essential. Thus, a primer of intertidal ecology is provided in Chapter 1.

Chapter 2 reviews the general planning considerations of various human activities along the coast and the potential impacts of those activities on intertidal environments. The goal of this discussion is not to discourage or argue against the development and use of our coastline. It is, rather, meant to encourage and provide some guidelines for sensible planning. Along the coast, as elsewhere, proper planning can direct development and other activities to the most appropriate sites, maintain the benefits of multiple uses, reduce or prevent unnecessary adverse impacts on the environment, and help developers avoid costly delays and legal conflicts. Basically, the impacts described are of a common or major nature. An attempt has been made to avoid giving equal emphasis to comparatively minor problems.

Chapter III provides a concise overview of the geological and biological characteristics of nine basic types of intertidal habitats. In addition, it describes some of the special planning considerations associated with them. Although this handbook can stand alone as a reference, it is more helpful when used in conjunction with a set of coastal resource inventory maps entitled, "The Coastal Marine Geologic Environments

Maps." These maps show the locations of distinct coastal environments, such as mudflats and beaches. The features and uses of these maps are described in Chapter 3. (More detailed information can be found in the companion volume to this handbook, *The Geology of Maine's Coast*, also available from the Coastal Program.)

Chapter 4 describes some of the creatures inhabiting Maine's intertidal areas.

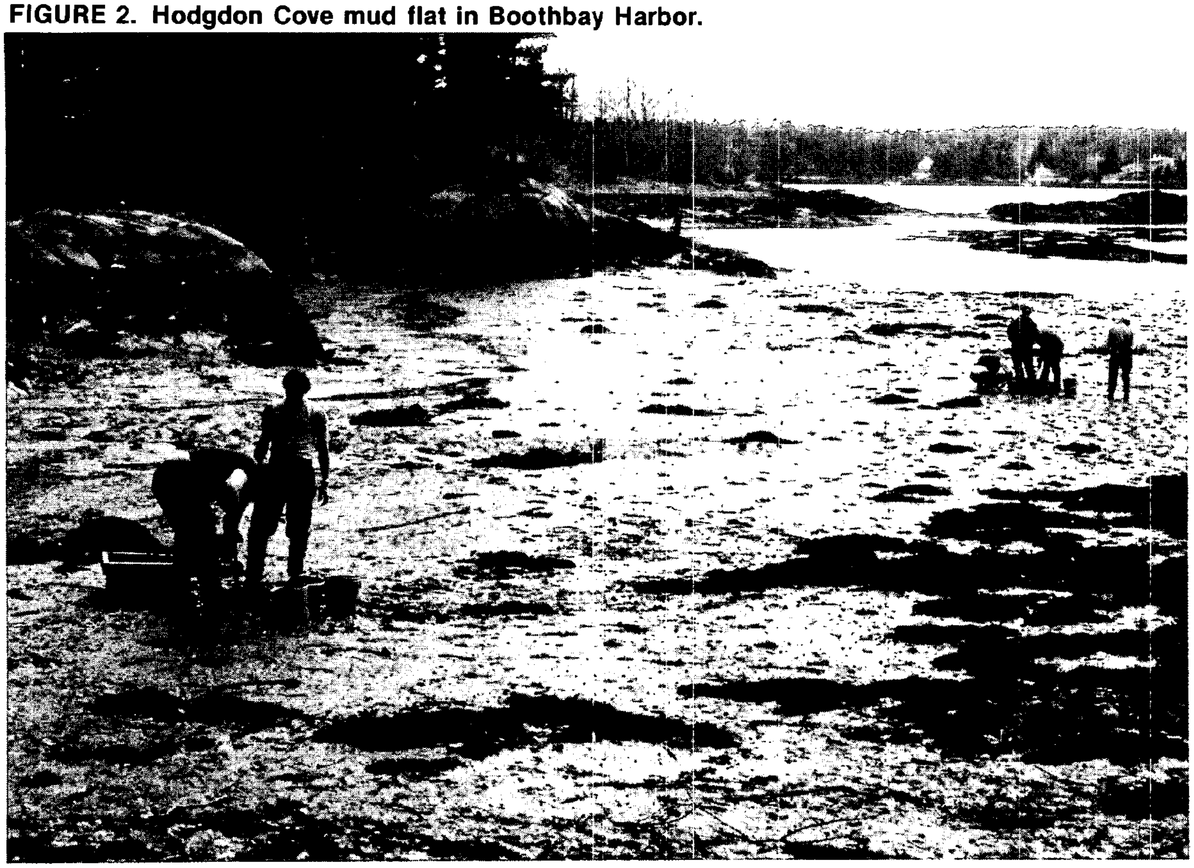
The harvesting of clams, bloodworms and sandworms from intertidal mudflats employs thousands of Maine residents (as diggers, wholesalers, shippers, processors and retailers) and brings tens of millions of dollars into the state each year. Smaller fisheries exist for various seaweeds (extracts of which are used as food additives and fertilizers) and for other species, such as periwinkles.

The intertidal zone also provides many indirect economic benefits. For lobsters, crabs, winter flounder and other commercially valuable species, small intertidal organisms comprise a major source of food and a crucial link in the complex food chains of the sea. A great number of those commercial species also spend the early stages of their lives in intertidal habitats. Many kinds of shorebirds and waterfowl, sought by both birdwatchers and hunters, feed in intertidal and shallow subtidal habitats.

Each year, tourists and Maine residents generate millions of dollars of economic activity through their recreational use of the intertidal zone. They come to swim, sunbathe and surf fish on Maine's beautiful beaches. Some drive thousands of miles to gaze at the magnificent splendor of Maine's fabled rocky shores.

For these and other reasons, the people of Maine have a great stake in the wise use of the intertidal habitats along our coastline. It is intended this handbook will help ensure that these habitats retain their unique values now and in the future.

FIGURE 2. Hodgdon Cove mud flat in Boothbay Harbor.



CHAPTER 1

AN INTERTIDAL ECOLOGY PRIMER

Ecology is the study of the inter-relationships among living organisms and their environment. In the most general sense, this includes people and many of their activities.

Because such an all-encompassing field is so vast in scope, it has been divided into subunits, or branches, of study that are more narrowly defined and easier to research and understand. Of course, the basic natural laws which govern life apply equally to all branches of ecology. But the focus of each branch involves a unique set of plants, animals and physical conditions.

Intertidal ecology is the study of the relationship among the living and nonliving components of the intertidal zone, the intriguing area between the high and low tide lines. The bounds of the intertidal zone are not defined by any single high or low tide line, since these points shift considerably during the complex cycles exhibited by tides. Furthermore, the biological boundaries of the zone can be wider or narrower than the actual tidal range due to modifying influences of other factors, particularly wave exposure.

However, ecologists do distinguish between the truly physical intertidal zone and the "Littoral Zone", the region where biological communities grade from the subtidal (always underwater) to the terrestrial (always above water). And, though the two terms are commonly used interchangeably, our discussion will differentiate between them in the beginning. First, we will focus on the true intertidal zone, discussing the effects of tides and how living organisms respond to tidal cycles. Then, the concept of wave exposure will be introduced to show how important this is as a modifying factor.

Tides

In a sense, tides are very long waves created on the ocean by the gravitational pulls of the sun and moon. They should not be confused with so-called "tidal waves," which are large, destructive waves caused by earthquakes rather than gravitational pull. Tides occur throughout the ocean, though they are most easily noticed along the coast, where their rise and fall alternately covers and uncovers a portion of the shoreline, the intertidal zone.

Due to the combined effects of the gravitational pulls of the sun and moon and the earth's rotation, there are normally two low-to-high tidal cycles each day (more accurately, every 24 hours and 50 minutes). The highest and lowest points reached by these semi-diurnal, or twice-a-day, tides vary during the year. When the earth, moon and sun are aligned in space, which usually occurs at or shortly after the full moon and new moon, the pulls of the sun and moon reinforce each other. Both are pulling in the same direction. This makes the high tides higher than average, the low tides lower, and the tidal range — the difference between the high and low tides — greater. These monthly periods of relatively great tidal ranges are called "spring tides", the term coming from the ancient Germanic verb *springen* (to leap up). The smallest tidal ranges, called neap tides, occur when the earth, moon and sun form a right angle to each other at the half-moon phase. A complete spring-to-neap-to-spring tide cycle occurs every two weeks, as a result of the relationship to the moon's monthly orbit. This cycle is illustrated in Figure 3.

Monthly cycles are not the only regular changes noted in tidal ranges. During the year, the distance between the earth and sun varies. So, too, does the angle at which the earth "faces" the sun. Thus, there are annual variations in tidal range. In Maine, for example, the greatest tidal ranges occur during spring tides occuring in the spring and fall.

Another important factor controlling tidal range along our coast is the shape of the Gulf of Maine and Bay of Fundy. In general, their configurations lead to greater tidal ranges the farther east one goes. The mean tidal range in Maine varies from about eight feet (2.4 meters) in Portland to eighteen feet (5.5 meters) in the Lubec/Eastport area. This is significant because the intertidal zone is normally wider where there is a larger tidal range (depending on the slope of the shore).

The physical intertidal zone, then, is defined as that area between the extreme low water mark and the extreme high water of the year's highest spring tide. Each part of the substrate — the rock, sand, mud, and gravel — in this zone is entirely covered by ocean water at least once a year during the highest spring tide and completely exposed to the atmosphere at least once a year, during the lowest spring tide. During the extreme neap tides of the year the sea covers the least amount of area above mean tide level at high tide and exposes the least amount of bottom at low tide. (See Figure 4).

Most daily tides have a range somewhere between the extremes of the neap and spring tides. For this reason, it is useful to speak in terms of "mean high water" or "mean low water", which simply refers to the average positions of high and low water during an average tidal cycle. "Mean tidal level" is the term used to denote the overall average level of the water, the point midway between the highest and lowest tide marks.

FIGURE 4. The various tidal levels and ranges discussed in the text.

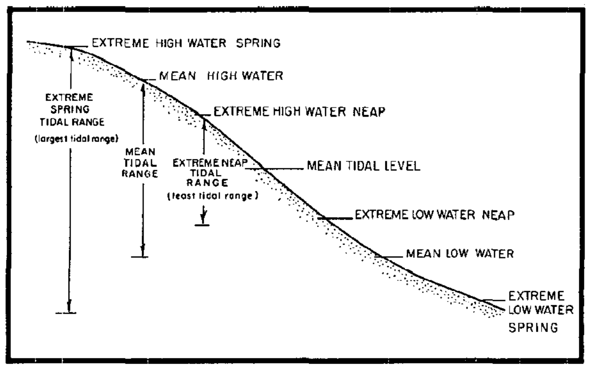
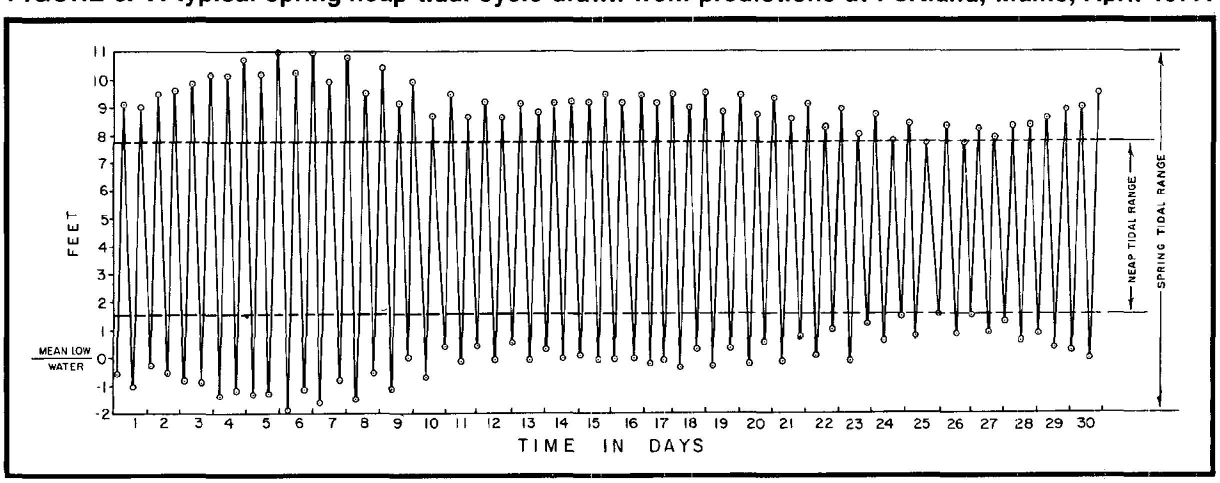


FIGURE 3. A typical spring-neap tidal cycle drawn from predictions at Portland, Maine, April 1977.



The Ecological Significance of Tidal Height

The plants and animals that live in the intertidal zone are, for the most part, creatures of the sea and are thus closely related or very similar to subtidal species. Like all marine organisms, intertidal plants and animals are dependent on the sea for their oxygen and food supplies, the removal of body wastes, and as a medium in which to reproduce and disperse their offspring.

However, living in the intertidal zone requires certain unique physiological adaptations. By and large, the greatest problem faced is dessication — drying out — during periods of exposure to the air. Life began in the sea, and before survival could be assured on land, mechanisms had to be evolved that would prevent individual organisms from drying out. We see the ultimate results of this evolutionary process in land animals that have developed special external membranes (skin), complex execretory systems that conserve body water, and internal respiration systems (lungs). These adaptations also serve to maintain relatively constant temperatures and other physiological conditions within an individual land organism.

In contrast, the rate of metabolism in marine invertebrates (ocean species without skeletons) is generally more strongly influenced by environmental temperatures. At colder temperatures, they feed, respire, and grow more slowly than at higher temperatures.

Thus, as opposed to terrestrial species, most marine invertebrates are not greatly adapted to drastic variations in environmental conditions. Intertidal plants and animals must, by necessity, have some adaptations that allow them to survive the comparatively harsh extremes that occur during periods when they are exposed by low tides. However, they are not nearly as well adapted in regard to physiological prevention of dessication or temperature regulation as land organisms. They can survive exposure for short daily periods, but not for considerable lengths of time.

This makes the periodic variations in tidal range a crucial ecological factor. It is, in fact, the primary influence that determines where different kinds of intertidal species can survive along the shoreline.

As shown in Figure 4, the cyclic variations in tidal height create fairly distinct "layers" within the overall intertidal zone of a shoreline. Each layer is affected by a particular set of environmental conditions based on tidal fluctuations. Their horizontal width depends on the slope of the shoreline. In combination with the type of geological substrate (i.e., whether the shoreline is composed of sand, gravel, rock, etc.) and certain other factors, the tide-related conditions affecting these layers determine the kinds of plants and animals that can live within them.

The upper intertidal region, between the extreme high water spring and mean high water lines is one step short of being a truly terrestrial environment. It is covered by spring tides on only a few days of each month and organisms living there must withstand many days of continuous exposure to the atmosphere. This is a harsh situation very few species can tolerate. The ribbed mussel, *Geukensia demissa*, is such a species that occurs in Maine.

The area between mean high water and extreme high water neap offers less harsh conditions, though plants and animals residing there must still tolerate extended periods of exposure — up to 24 hours just above the extreme high water neap line, increasing to several days as the extreme high water spring level is approached.

Organisms living between the high and low neap tide lines are exposed to the air for some period of hours during every tidal cycle. This means they must be able to bear the effects of exposure on a regular basis. But, since they are also covered by the tide during each tidal cycle, they do not have to be adapted to surviving more than a few hours of exposure at a stretch.

Organisms living between extreme low water neap and mean low water, receive somewhat less exposure to the atmosphere and are continuously submerged for days at a time during the month. Those in the lowest intertidal area, between the mean low water and extreme low water spring lines, are submerged most of the month and exposed to the atmosphere on very few days. In fact, this shoreline environment is not greatly different from the constantly-submerged subtidal region.

During low tide periods, organisms living above the low tide level are subjected to stresses far greater than those in the subtidal realm. These conditions include the extreme cold of winter, the extreme heat of summer, the drying action of the wind, and stress caused by the influx of fresh water during heavy rains (most marine species can't survive long in fresh water).

Because of the progressively harsher conditions in the intertidal zone between the extreme low water spring and high water spring levels, the intertidal environment can be considered to exhibit a "stress gradient". Not only does the frequency of atmospheric exposure increase steadily along this gradient in relation to the height of the layer, so does the length of the period of continuous exposure that must be survived.

The severity of any given stress depends in part on the time of day at which a low tide occurs. For example, in winter, the threat of freezing is greater during low tides that occur in the cold early morning hours than during those occuring at midday. In summer, low tides that occur in the early afternoon create a greater threat of drying out than those which happen in the morning, late afternoon or night. Similarly, heavy rains at high tide have little or no effect on intertidal organisms, while a downpour at low tide exposes them to very low, un-oceanlike salinities which can cause extreme stress or even death.

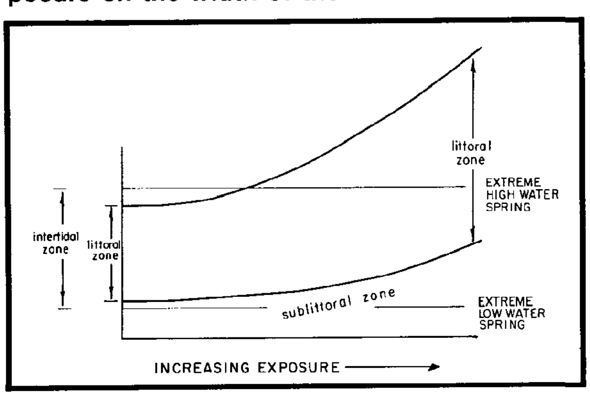
Other environmental dangers to organisms in the intertidal zone include the threat of being crushed or dislodged by crashing waves or by ice, logs and other debris that may grind along the shoreface as the tide rises and falls.

Wave Exposure

Although tidal range defines the size of the physical intertidal zone, the effective biological intertidal zone in which intertidal species may live can be expanded by wave action. This depends on the degree to which a particular stretch of shoreline is exposed to waves.

In a shore completely protected from wave action, such as a quiet, enclosed bay, the high tide line determines how far up on the shore intertidal organisms can live. The more a shoreline area is exposed to the wave action of the open ocean, however, the higher the upper intertidal zone is pushed landward. This is because waves break on the shore and wash over, or splash onto, elevations above the tide

FIGURE 5. The effect of the degree of wave exposure on the width of the littoral zone.



level, creating enough moisture for upper intertidal plants and animals to survive. The greater the exposure to wave action and the larger and more consistent the waves are, the more pronounced the effects on the landward extent of the intertidal area. Figure 5 illustrates this phenomenon. It graphically shows the difference between the physical intertidal zone and the biological intertidal zone, or "littoral zone". A protected shoreline situation is represented at the extreme left. The littoral zone here is actually narrower than the physical intertidal zone, because the lower intertidal area is occupied by organisms that are essentially the same as those found sub-tidally rather than by true intertidal species. In addition, the absence of wave splash means water covers the uppermost intertidal area on only the most extreme spring tides, once or twice a year. Hence, intertidal organisms can't survive there.

The effects of increasing wave exposure are shown at the right of the graph in Figure 5. As wave action increases the littoral zone moves landward, higher on the shoreline. In highly exposed shoreline, the littoral zone becomes wider than the intertidal zone. Under such conditions, indicated at the far right in the graph, some subtidal species can occur well up into the lower intertidal zone and many intertidal plant and animal species can live above the extreme high water spring tide mark.

Throughout the rest of this handbook, when the term "intertidal zone" is used, it will mean the littoral zone, as opposed to the actual physical intertidal zone.

Other Ecological Factors

Tidal range and wave exposure are not the only ecological factors that determine the extent of the intertidal zone along a given shoreline area. A significant factor related to wave exposure, is the slant, or slope of the shoreline. The slope of a shore affects how high waves will surge landward, before their energy is dissipated, as well as how quickly the water will drain off.

In flat, wide shores, water from incoming waves does not surge and splash very high, but it drains off relatively slowly. This increases the available moisture and lessens the threat of dessication to the plants and animals living there. As the slope of the shore becomes steeper, the extent and effect of wave surge and splash generally increase. However, with increased steepness there is also increased drainage. On a rocky shore exposed to heavy wave action, wave surge allows some intertidal species to live at a higher level than on an exposed flat shore. But in protected areas, the rate of drainage becomes the critical factor, and on very steep shores intertidal species are usually limited to a lower level.

The actual structure, or substrate, of the shore — that is, what it's made of — is another important factor controlling what species can live on it. Bedrock shores are very stable. Thus, they can be colonized by intertidal organisms that can establish a firm hold on the rock, such as barnacles. Sedimentary environments composed of gravel, sand or mud, create very different conditions. For example, some cobble beaches can be quite inhospitable to most living organisms because the individual rocks may be moved regularly by waves, crushing the organisms that might settle on or between them. Likewise, since the small top layer of grains on a sandy beach shift with every wave, sand can be colonized only by fast-burrowing species which can constantly adjust their positions with respect to the surface of the beach.

The composition of the substrate in a sedimentary environment also controls the amount of water that remains in the spaces between the sediment particles at low tide. In a sand beach with relatively large grains, water easily drains away from between the particles, exposing any organisms there to dessication and the temperature extremes of the air. In mud and other fine-grained sediments, water remains in the "interstitial" spaces between grains at low tide. This affords the species living there a greater degree of insulation against environmental extremes.

In addition to dryness and temperature, marine organisms are sensitive to reductions in the salinity, or salt content, of water. When they are put into water of lower salinity than seawater, they tend to swell, as the fresher water diffuses by osmosis into their bodies. Some intertidal species have a limited ability to make adjustments to salinity changes if they are not too great and do not occur too rapidly. However, many species cannot survive any significant salinity reduction and are thus unable to colonize places where build-ups of fresh water tend to occur. Such places include sites where rivers or streams enter the intertidal zone and those where fresh water seeps in from the water table. Also included are exposed parts of the intertidal zone during rains. The effect in this case is greater in the upper part of the zone, which is subject to the rain for a longer period of time.

Light is a factor in the intertidal zone in much the same way as on land. For example, areas facing south receive more sunlight and warmth than those facing north and, hence, are likely to be drier when exposed. Heavily shaded places, such as cracks, crevices, and the undersides of rocks, dry out more slowly than surfaces exposed to the sun and individuals living there are less subject to dessication.

The general climate of Maine cannot be underestimated in its influence on the composition of intertidal communities living along our shores. Many species need a summer temperature above a certain minimum to induce spawning. If that temperature is not reached in a given year, those species will not spawn. This limits how far north some intertidal species will be found, even if other conditions might be suitable. An example is the American oyster. It is fairly common south of Maine, but exists here only in localized pockets of warm water.

The extremes of the Maine winter are another crucial climatic factor. During periods of exposure at low tide, freezing of tissue can be a threat to intertidal organisms. The higher in the intertidal zone a plant or animal lives, the longer their exposure to the cold and the greater the threat of freezing.

Ice is another danger. As the tide moves in and out, floating chunks of ice can crush intertidal organisms or dislodge them from their substrate. When ice settles on a tidal flat at low tide, the upper sediments and any organisms living on or in them can be frozen into the ice and floated away with the next tide. Finally, during very cold weather the water in an intertidal area can freeze all the way to the bottom and suffocate or freeze everything living there.

Zonation

As explained earlier, tidal cycles create fairly distinct parallel bands in the intertidal zone that are colonized by different kinds of plants and animals. This phenomena is called "zonation". Zonation of the intertidal shoreline is a general feature that can be seen nearly anywhere along the Maine coast. It is most easily observed on a bedrock shore, where all the organisms live on the surface of the substrate (as opposed to mud or sand, in which they can burrow).

Between the subtidal area and dry land on a rocky shore, zonation can be seen as a series of dark red, brown, white and black or gray bands. The colors are those of the dominant species in each band. The color of the red band results from the abundance of the red algae, *Chondrus crispus,* commonly called Irish moss, which predominates at the lowest intertidal level. The brown band above it is colored by the various rockweeds common to Maine, brown algae from the genera *Ascophyllum* or *Fucus*. The notable white band is made up of a pavement of barnacles *(Balanus balanoides)*. The color of the next highest band, often called "the black zone," is caused by a film of dark-colored, blue-green algae that grows on the rocks. Like the species that create these colorful bands, most other intertidal plants and animals live within a distinct layer of the intertidal zone, but they are generally not abundant enough to create a colored band of their own.

Intertidal organisms are basically limited to their particular band by their physiological adaptations, which allow them to survive certain ecological factors. Some of these factors are physical and some are biological.

The upper limit at which a given intertidal species can exist is controlled primarily by physical factors, the most important being tidal height and wave exposure. For example, the extreme high water neap tidal level is a physical boundary for those species that cannot tolerate more than a few hours at a stretch out of the water.

The more tolerant an animal is to such stresses as dessication, heat, cold and rain, the higher in the intertidal zone it can live. Thus, in the intertidal zone from low water up through the succeeding levels, one after another species drops out, and several with similar tolerances may drop out at one point. Those points where a number of species cease to exist can be considered the upper boundaries of the internal bands, or zones, of the overall intertidal zone.

In contrast to the upper boundaries, the lower boundaries of these zones within a zone are not limited by physical factors. Since all intertidal species are marine organisms, they are capable of living and thriving underwater for any length of time.

What are the principal factors creating the lower boundaries? In general, they are the biological factors of competition and predation. A simple example from Maine's rocky intertidal zone is the barnacle, *Balanus balanoides*, and its relationship with the blue mussel, *Mytilus edulis*, and the snail known as the dog whelk, or *Nucella lapillus*. In the upper level of the intertidal zone, barnacles are the dominant animal species, forming a solid, fairly wide, white band. The upper limit of the barnacle zone exists at the point where inundation by high tides is so infrequent the barnacles' tolerance limit to dessication is reached. Barnacles can easily survive the physical conditions of lower intertidal levels. However, under natural conditions they are not found there in abundance due to biological pressures from the blue mussel and the dog whelk.

In exposed shores, the lower edge of the barnacle zone is usually set by the upper limit of the intertidal range of the mussel. Mussels are superior to barnacles in their ability to compete for living space on the rocks. Therefore, in the area where both species can survive, the presence of mussels tends to make it impossible for barnacles to gain a foothold. So, the barnacle is relegated to colonizing a higher level, at which the mussels can't exist.

In more protected shores, another pressure is added by the predatory dog whelk. Dog whelks prey on both barnacles and mussels. They cannot stand as long an exposure to the atmosphere as barnacles. Thus, the lower limit of the barnacle zone is set by the dog whelk's upper tolerance limit to dessication. Most barnacles that settle below this lines are devoured by the voracious snails. Barnacles can occur in abundance only above the level that can be reached by dog whelks.

Scientists believe that biological interactions similar to those between barnacles, blue mussels and dog whelks determine the lower limits of most intertidal species' life zones. Most of these other relationships are much more complex and little understood at this time. However, current and future research should eventually help ecologists understand more about the zone-determining effects of competition and predation in the intertidal zone. In turn, this may lead to theories that can be applied to more complex environments.

FIGURE 6. The salt marsh, just north of Route I-95 on the Cousins River, Yarmouth.

CHAPTER 2

GENERAL PLANNING CONSIDERATIONS

First Steps, Basic Factors

Intertidal organisms are, by necessity, a hardy lot, adapted to living in an inherently stressful environment. Compared to their subtidal relatives, they have broad tolerance limits to natural environmental stresses. In general, they are also more resistant to stresses caused by pollution or other impacts resulting from human activities. Nonetheless, they *are* susceptible to lethal or sub-lethal damage by a wide range of pollutants and man-made changes.

Research on the environmental impacts of human activities is being carried out today at an unprecedented rate, both in the field and in the laboratory. Still, we currently have a very limited knowledge of how various activities or pollutants will affect a given environment and its inhabitants. The need for further research is especially great with respect to our valuable intertidal environments. Though major initial impacts can often be predicted with some certainty, more subtle sub-lethal of long-term effects are mostly unknown. For example, while scientists predict the quick deaths of clams smothered by a heavy coating of oil spilled from a tanker, informational gaps make is extremely difficult to predict the effects of chronic "low-level" oil pollution, or the long-term effects of trace amounts of oil on intertidal mud.

Many of the basic facts which are currently known about the effects of pollutants and certain coastal activities on intertidal organisms are reviewed briefly in this Chapter, along with some related general planning considerations.

Some of the special planning considerations assocated with specific intertidal environments are described in the following Chapter.

One of the most important steps needed to properly plan or review developments and other major activities along the coast is to contact the appropriate government agencies. Under current laws, virtually all projects located in or near intertidal areas require permits from either municipal or state agencies. Most require both town and state permits. Some activities, such as dredging, also require approval from federal agencies. Thus, planners and developers should be aware of, and carefully follow, all necessary application procedures.

Problems in securing permits can often be avoided if applicants find out about all relevant legal restrictions as early as possible. (Most of the pertinent laws and administering agencies are listed in Figure 23 of this handbook.)

Frequently, in addition to reviewing projects as part of permitting procedures, state agency officials can provide technical assistance in siting and designing developments or activities so that they will meet existing legal standards. However, developers should, and usually do, hire private consultants to help them design their projects. This often provides greater assurance that projects will be designed consistent with municipal, state or federal guidelines, and more likely to receive the necessary permits.

Petroleum Hydrocarbons

Maine has taken the lead in responding as a state to the threat posed by oil pollution to the coast. Recognizing that, in terms of tonnage, more crude petroleum and petroleum products are handled by Portland than by any other New England port, and that oil terminals in Harpswell and Searsport are supplied by ocean going barges and tankers, landmark legislation providing for regulation to prevent oil spills and for effective response to accidents was passed in 1970. The Hazardous Waste Division of the Maine Department of Environmental Protection maintains emergency standby capabilities and contingency plans for swift cleanup measures in case spills occur in the high oil traffic areas such as Casco Bay and Penobscot Bay.

This extensively organized effort to prevent and contain major accidents as well as more frequent, smaller oil spills is justified by past events such as the grounding of the tanker Northern Gulf in 1963, of the tanker Tamano in 1972, of the tanker New Concord in 1979, and the underground pipeline leak at Searsport in 1971.

Intertidal areas are also subject to oil and oily wastes originating from households, industry and motor vehicles and transported by storm runoff through the drainage systems of coastal communities. These incidents underscore the belief of many marine scientists that oil pollution poses the most serious threat facing the intertidal habitats of Maine.

Oil can kill or adversely affect marine organisms in several ways. Following a spill, asphyxiation, or death by smothering, is a primary cause of mortality in the intertidal zone. Barnacles are especially susceptible if the coating of oil is thick enough to be higher than the tops of their shells. A coating of oil on rock surfaces can also cause periwinkles and other species to lose their hold on the rocks and be washed away by the waves.

Many marine species can be poisoned and killed quickly if their exposed fleshy parts come in contact with oil. Deposit-feeding organisms, such as marine worms, can be poisoned by ingesting organic materials or sediments coated with oil. Also, contrary to popular belief, oil and water do mix to a certain extent. In fact, many of the toxic components in petroleum products dissolve in water and can kill or harm organisms that pass oil-polluted water through their respiratory systems.

A particularly significant impact of oil pollution is the destruction of the juvenile forms of marine species. Larval and juvenile forms are generally much more sensitive to oil than adults. This means that the young, the future generation of a species, can be wiped out by oil pollution even when the adults survive. As a result, an investigator reporting that an oil spill had no effects on a clam flat because he discovered adult clams were still present, may have overlooked the major catastrophe represented by the loss of juvenile clams. Frequently, larval mortality from spills is compounded by the fact that oil can remain in fine sediments for a period of many years. Although the adult population may survive and even reproduce after an oil spill, each new generation of larve may die as soon as they enter the contaminated sediments. Thus, the total population of the species suffers and may decline from a lack of recruitment.

Non-lethal effects on marine organisms from oil pollution so far reported include development of abnormal tissue growths in clams, delayed molting in lobsters, abnormal sexual behavior of fiddler crabs, abnormal development of barnacle and sea urchin larvae, and disruption of the sensory mechanisms of lobsters, amphipods, and mud snails. Oil destruction of larval forms and other organisms low on the food chain may reduce the overally productivity of a marine habitat.

Exposure to wave action and sediment composition are the two major factors controlling how much damage an oil spill creates in an intertidal area and how long adverse impacts last. On high-energy shores, exposed to heavy wave action, oil is often dispersed relatively quickly by waves. In low-energy areas protected from heavy wave action, oil may persist for years. Rocky shores are most easily cleaned of oil by waves, tides, and rain. Cobble beaches and gravel beaches are most easily cleansed than sand beaches. Sand flats, mud flats, and salt marshes are the least easily cleansed habitats.

Although residents of coastal towns cannot control tanker traffic offshore, they can become familiar with procedures for responding to oil spills from tankers or other sources by contacting the Department of Environmental Protection. In terms of general planning considerations, they can carefully evaluate the siting, construction, maintenance, and operation of local off-loading or storage facilities for petroleum products or any other projects that involve the potential for major or chronic oil pollution problems.

Dredging

Dredging is the removal of sediments from intertidal, subtidal or wetland habitats. Most dredging in Maine is done to maintain or open up channels of navigation. Less frequently, dredging is undertaken to obtain sand, shell or gravel deposits, or to prepare a coastal site for construction. Whenever dredging is planned for any purpose, the potential effects on marine environments in the vicinity must be carefully analyzed as part of the permitting process.

The basic methods used in dredging are mechanical and hydraulic. In mechanical dredging a crane with a large bucket loader or a power shovel is used to remove sediments. The sediments, referred to as "spoil", are dumped overboard or onto a barge that transports its loads to a disposal site. Hydraulic dredging involves the use of powerful pipeline dredges that suck up the sediments and transport them by suction pipe to a disposal site. In Maine, mechanical dredges are usually employed due to the relatively coarse nature and low volume of the materials dredged here.

Dredge spoil along our coast generally consists of sand, soft mud and small amounts of rocks. The areas most frequently dredged in Maine during the past twenty years are Portland Harbor, the Kennebec River, the Penobscot River, Rockland Harbor and the Royal River. (A list of recent dredging locations and disposal sites is given in Table 11, p. 57, Data and Analysis for the NE/LI NERBC "Dredging Management: Sound Region", 1981.)

Dredging involves environmental impacts that should be carefully considered. These impacts result both from the removal of sediments and from their disposal. Dredging removes bottom-dwelling plants and animals along with the sediments. Indeed, newly-dredged areas tend to be virtually devoid of life and their physical and chemical properties are often very different from natural habitats. In time, dredged areas can be recolonized by marine organisms, but they are generally less productive than they were before the dredging occurred. In addition, dredging tends to create an unstable sediment configuration on the bottom that leads to fast sediment build-up requiring further dredging. Repeated dredging in an intertidal or subtidal area prevents a normal mature community of marine species from becoming that area's contribution to the surrounding ecosystem.

Dredging can also change local current patterns. Since the type of sediments deposited in an intertidal or subtidal habitat depend largely on current speed and direction, a change in current may lead to a marked change in bottom sediments. The type of sediments in an area determine, in turn, what kind of plants and animals can live there. As a result, current alterations caused by dredging can lead to significant changes in the types of plants and animals found in and around a dredged area. It may, for example, reduce the amount of clams available for commercial harvesting by changing the character of local mudflats.

A common effect of dredging is increased water turbidity. During dredging operations, large quantities of mud and silt are stirred up into the water. This underwater cloud of sediments can reduce the survival rate of tiny shellfish larvae and juvenile fish that live in the water column. As it resettles it may smother or foul the respiratory organs of clams, mussels, and other species. The extent of the turbidity depends on the type of sediments being dredged, the dredging method used and local water currents. The effects may be short-term and localized in some cases. In others, the distrubed silt may be resuspended again and again by tidal and wind-driven currents and adverse effects from the turbidity may occur up to a half-mile from the dredging site.

Turbidity can also decrease the penetration of light through the water, thereby reducing the growth of floating planktonic or attached plants upon which other organisms feed. This phenomenon is generally not very significant in intertidal areas, but it is of special concern in deeper water, where light penetration may already be low.

When turbidity does seriously impair plant photosynthesis, the dissolved oxygen levels in a marine habitat may be reduced, an effect that may be made even worse as bacteria use up oxygen to decompose suspended organic sediments. Low levels of dissolved oxygen have sometimes lead to massive kills of marine invertebrates around dredge sites.

When dredging occurs in a polluted area, it can release poisonous hydrocarbons, toxic heavy metals and oxygen-depleting organic materials that were bound up in the bottom sediments. Plants and animals which absorb, ingest or come in contact with the chemicals and metals can be injured or killed. And, as explained, decomposition of organic materials released by dredging can lower dissolved oxygen to levels lethal to many species.

The disposal of dredge soil is not usually a major problem in the intertidal zone, since it is commonly dumped at sea. However, in some instances, spoil has been deposited in salt marshes, smothering and drastically decreasing the productivity of these important intertidal environments. Many of our commercially important shellfish and fish species spend part of their life cycle in a salt marsh habitat. Thus, dumping dredge spoil on salt marshes is considered a serious environmental problem and is not a recommended practice. In addition to the loss of habitat from a smothering layer of spoil, dredging in or near a marsh can lead to changes in the tidal flushing rate that may cause erosion and slumping of marsh banks.

The U.S. Army Corps of Engineers, which regulates dredging, has recently been conducting research to determine the feasibility of creating or reestablishing marshes on dredge spoil sites. Under certain conditions, the marsh-buildings techniques being developed by the Corps may allow spoil disposal on marshes to become an acceptable option where other methods are more expensive. Also, "beach nourishment", aimed at replacing sand lost from eroding beaches, is possible with suitable spoil materials.

Construction

Construction activities — the building of homes, walls, piers, jetties, dams, industrial or commercial facilities, roads, parking lots, bridges, walkways and other structures — can affect nearby intertidal environments in several ways. The most common problems are habitat destruction and increased turbidity. Such problems can occur as a result of preparatory dredging or when erosion on the construction site releases a heavy load of sediments that runs off into adjacent intertidal areas. The effects of turbidity caused by erosion are similar to those caused by dredging (see preceeding section). These adverse effects are normally of short duration as long as the construction does not alter local current patterns or flushing rates and erosion is not a persistent problem.

In contrast, bulkhead and pier construction or other developments actually sited wholly or partially within the intertidal zone can have long-lasting impacts. Most obvious is the direct loss of the potentially productive intertidal habitats displaced by the development. In addition, bulkheads, seawalls and piers can change local current patterns in ways that often cause scouring of surrounding sediments. This can lead to severe erosion or alteration of the bottom sediments and thus affect resident plants and animals. In Maine, direct and indirect loss of intertidal habitats due to pier and wharf construction is most notable in developed harbors such as Portland, Boothbay Harbor, Rockland and Eastport, where relatively large intertidal areas are covered by such structures.

A further effect of piers and wharves may be decreased productivity of plant and animal communities due to shading. The decreased availability of sunlight under piers and wharves is believed to reduce the growth of the tiny plants, called phytoplanktan, that live in the water column and the even more productive plant communities that live on the bottom sediments. In turn, this may depress local populations of the shellfish and fish that feed on these plants.

For planners and developers, two general areas of consideration should be addressed with respect to construction along or near the coast. First, the potential short and long term effects of the project on intertidal, subtidal and other environments should be thoroughly investigated with the assistance of relevant professionals. Secondly, construction methods should be planned and carried out in ways that will minimize erosion and any other impacts that could be avoided through careful forethought.

Shipping and Boating

Ship and boat traffic and their on- and off-loading can affect intertidal and shallow subtidal zones, directly or indirectly, in a variety of ways. One direct effect may be shoreline and bottom sediment erosion caused by the wakes of passing vessels. A more pervasive problem is that boats and ships powered by petroleum fuels comprise a significant source of chronic oil pollution along our coast. For example, research indicates up to one-third of the fuel used in outboard motors ends up in the water, and that this so-called exhaust water is toxic to many marine species. In addition, boats and ships require the loading of fuel in the intertidal zone. Despite stringent precaution, seeps and spills are a common occurrence during fueling operations. Oil tankers' spills and flushing procedures are another source of oil pollution along our coast. The varied effects of these are discussed in more detail above in the "Petroleum Hydrocarbons" section.

Shipping activity also commonly results in the release of human excrement, garbage, and other organic wastes into coastal waters. This can be a significant problem where there is extensive commercial boat traffic, such as in Portland Harbor or in confined harbors — especially during the summer when small boat and pleasure craft traffic is heavy.

Like untreated municipal sewage, extensive quantities of human wastes from boats can increase the threat of disease and prevent the harvesting of otherwise productive clam flats or even making swimming a dangerous proposition. Spills of toxic substances may also occasionally occur as a result of shipping activities. Normal maintenance activities, such as scraping, cleaning, and painting may lead to the release of certain other types of pollutants that are harmful to marine organisms.

Perhaps the most notable indirect effects ship and boat traffic have on intertidal environments occur as a result of the construction of support facilities — piers, wharves, marinas, bulkheads, etc. — which may destroy or adversely impact surrounding intertidal habitats. Obviously, a major planning consideration with respect to boating and shipping is the location of these support facilities. Whenever possible, they should be sited in locations that minimize short and long term environmental effects.

Biocides (Pesticides, Herbicides and Fungicides)

"Biocide" is a general term that can be used to refer to any of a variety of chemicals used in agriculture and forestry to control pests and diseases. These include: pesticides used to control destructive insects and animals; herbicides used to control weed plants; and, fungicides used to inhibit fungus growth on crops. When biocides are introduced into the intertidal zone or any other environment by accident or purposefully, there is often the potential for adverse effects on non-target plants and animals or people.

Effects can vary greatly from species to species, depending on the type and concentration of the biocide. Species high on a food chain are often most susceptible to severe effects due to biomagnification or increasing build-up, of the chemicals in the tissues of higher organisms. Examples can be seen in the fish and bird kills that have occurred as a result of pesticide use over the years.

Intertidal invertebrates and other lower organisms may ingest or absorb biocides when exposed to them. A few species low on the food chain are particularly sensitive to biocide contamination. Most notably, lobsters and other crustaceans, which are in the same taxonomic group as insects, may be harmed or killed by extremely low concentrations of pesticides.

Recent technology has lead to the development of biocides that are not as long-lasting in the environment as DDT and some other formerly popular agricultural chemicals. However, before the use of any biocide in or near the seashore or any stream or river entering it takes place, investigation should be made into potential effects on intertidal organisms as well as upon coastal residents. In addition to the site of spraying, attention should be given to concentrations used and methods of application. Furthermore, it should be remembered that most uses of biocides are controlled by state and federal regulations and that many uses require appropriate permits.

Heavy Metals

The group of pollutants called heavy metals includes lead, mercury, chromium, manganese, nickel, copper, zinc, arsenic, cadmium, silver and vanadium. Very small "trace" amounts of these metals occur naturally in soil, fresh water, and seawater. But, when the level of a heavy metal becomes unnaturally high in an environment, it can have adverse or even lethal effects on resident species — including humans.

Pollution by heavy metal is most often a result of industrial discharges. In Maine, for example, relatively high levels of certain heavy metals have been found in the water and sediments in or near the discharge areas of some pulp and paper mills, tanneries, municipal sewage treatment plants and mining sites. The concentration at which toxicity occurs varies with each metal and each species.

In general, heavy metals tend to build up in the body tissues of animals, resulting in the same kind of "biomagnification" noted for pesticides — that is, the higher an organism is up the food chain in an environment polluted by metals, the greater the concentration of the pollutants in its tissues and the greater the possibility of adverse physiological effects. Depending on the species, the metal in question, and its concentration, those effects can include behavioral disorders, genetic defects, disruption of organ functions, or death. The major concern into the intertidal zone is the potential effect on the health of people who might eat contaminated clams, mussels, or other intertidal organisms. Since heavy metals can be accumulated in the body, a person eating enough contaminated shellfish or fish may develop heavy metal poisoning.

Current state and federal regulations limit the concentration of heavy metals allowed in industrial effluents as well as in fish and shellfish sold commercially. Thus, when the siting of industrial development or mining along the coast is considered, the potential for heavy metal pollution of local intertidal environments should be investigated. Monitoring of heavy metal concentrations in intertidal environments near existing industrial discharge areas may also be a wise precaution. Another possible source of heavy metal pollutants is a sanitary landfill, from which metals may leach into surrounding waterways. Recently, some scientists have also become concerned that under some circumstances "acid rain", caused by sulfur dioxide and nitrogen oxide pollution from coal and oil-fired power plants, factories and automobiles, may leach heavy metals from the soil, thus releasing them into water bodies.

Dams

Damming or otherwise impounding a river mouth for conventional hydropower, or damming a bay for tidal power can have major effects on local intertidal environments. These effects may be deemed an acceptable trade-off in the final analysis of a specific dam project. However, they must at least be investigated and considered in order to receive the necessary state or federal permits. Current regulations exist in part to ensure that the benefits of a dam outweigh its adverse environmental impacts.

The potential impacts of a conventional dam near the mouth of a river on nearby intertidal environments such as the salt marshes and mud flats in river-mouth estuaries include alterations in the volume and flow of freshwater and subsequent changes in salinity, sedimentation rates, circulation patterns of the water, temperature, shoreline erosion, nutrient levels and other crucial factors.

Such changes in the chemistry and flow of the water and the stability of the geological substrate may have major effects on the resident communities of plants and animals. Small variations determine what types of crustaceans, shellfish, fish, plants and other species can survive and reproduce in a given environment.

Where impoundments alter downstream sediment flow and act as settling basins, they may also contribute to gradual erosion of nearby beaches or other geological environments that may have depended on the former influx of sediments to maintain their sand supply.

Though tidal power projects are still in the future on our coast, some researchers have already become concerned about the possible environmental side-effects of damming coastal bays. Existing tidal projects in other countries and preliminary impact studies of planned tidal schemes indicate that tidal impoundment may significantly alter tidal range, current flow, water temperature, wave action, sedimentation and erosion patterns and other factors in and around a dammed bay. These changes, in turn, may adversely effect the plants and animals. For example, under most conditions, a tidal project would be expected to shrink the tidal range within a dammed bay, thus reducing the habitat available for clams, mussels, and other valuable intertidal species.

Impoundment might also be expected to decrease the flushing rate of a bay, preventing the organisms within from receiving as much food and oxygen as previously and allowing a possible harmful build-up of waste products to occur. In the case of large tidal projects, adverse impacts resulting from changes in tidal range may also occur outside of impounded bays in intertidal areas for many miles around.

Toxic Substances and Hazardous Wastes

Although incidents such as those at Love Canal, New York and East Gray, Maine have made us all more aware of the threat to people from hazardous wastes and toxic substances, we may sometimes forget that poisonous chemicals also pose a threat to other living species. Maine industries use hundreds of different chemicals and produce hundreds of thousands of gallons of hazardous wastes each year. State regulations now require "cradle-to-grave" accounting for all toxic substances. There are also regulations regarding the use, transportation and disposal of most of these chemicals. For example, it is now illegal to dispose of hazardous wastes of any kind in a town sanitary landfill. Town and industry planners on the coast, as elsewhere, must consider these things in planning or undertaking any activity dealing with toxic substances and hazardous wastes.

If poisonous industrial chemicals do pollute an area of the intertidal zone, the effects will depend on many factors: the type and quantity of the chemicals, the geology and hydrography of the site, the type of organisms in the polluted area, and so forth. Effects could range from minimal to disastrously lethal. Suffice it to say that toxic substances and hazardous wastes should be properly used and disposed of at all times, and every attempt should be made to keep them out of the intertidal zone or any other natural environment.

Recreational Activities

Recreational use of the intertidal zone is commonly concentrated on sandy beaches. This is an environment of relatively limited occurrence in Maine, which has only about 30 miles of large, open, easily accessible beaches, primarily located along the southwestern half of the state's coastline. Numerous small barrier and pocket beaches are scattered among the inlets and islands making up irregular 4,000 mile shoreline in Maine, but these are generally far less accessible than the larger beaches.

Beaches themselves are high-energy dynamic environments well able to stand the impact of many users. On the other hand, the dunes lying landward of many beaches are very fragile elements of interdependent dune-beach systems. Even unregulated foot traffic, by destroying beach grass, can lead to significant dune erosion. This can lead, in turn, to disruption of the dune-beach sand cycle and hence to erosion of the beach proper. Similarly, off-road vehicle traffic, construction and other disturbances of dunes can have secondary adverse impacts on beaches.

Gravel, cobble and boulder beaches are not nearly as popular for recreational activities as sandy beaches, though most common types of recreation would have little impact on them. Some sand flats and mud flats are used for the recreational digging of clams. However, this activity rarely reaches the intensity of commercial clam or worm-digging efforts.

Although rocky shores and marshes are not as popular as our large beaches for recreation, heavy use at places of general public access can sometimes be a problem. For example, excessive collecting can reduce the populations of organisms living in tide pools and other intertidal habitats. This is why permits are required to collect intertidal plants and animals in national parks.

Commercial Digging of Clams and Worms

Where extensive digging takes place for clams and marine worms, large portions of the surface mud and sand flats may be overturned. This exposes many burrowing intertidal organisms not gathered by the diggers, including juvenile clams and worms, to stresses they may not be able to tolerate — the summer sun, rain, winter cold, etc.

Where substantial mortalities occur among juveniles, and where adults have been overharvested, the abundance of affected species will decline and the flats will be less productive. Extreme overharvesting can effectively eliminate populations of clams and worms sought by both the recreational and commercial diggers. Thus, coastal town officers should, and often do, monitor and regulate clam harvesting on local flats.

Thermal Effects

Power plants, factories and other industrial operations located on the coast sometimes release discharges into intertidal areas that are warmer or cooler than the ocean temperatures. In some cases, warm-water discharges free of toxic pollutants may enhance the prospects for aquaculture ("fish farming") within the discharge area. Along much of Maine's coast, for example, oysters can only be raised successfully where ocean temperatures are made higher than normal by warm-water discharges or impounding. Salmon culture may also be much improved in discharge-warmed waters. However, many other resident intertidal species cannot survive any significant warming or cooling of the waters beyond that which takes place naturally.

Heating the water is the most common and potentially the most serious thermal effect of industrial discharges. Many native species in a heated area may not be able to survive, especially those who were already living near the southern extreme of their range. In general, the effects are even more serious in subtidal environments, because subtidal organisms tend to have less tolerance to thermal changes than intertidal plants and animals.

The effects of cooled water, such as might exist around a liquified natural gas (LNG) plant, are not well known. The most significant may be that the temperatures needed for spawning of some species would no longer be reached.

Whenever industrial discharges, thermal or otherwise, are to be released into intertidal areas, appropriate state or federal permits must be sought. This permit process makes it necessary to investigate the potential for adverse effects on intertidal environments.

Sewage and Organic Wastes

In recent decades significant progress has been made toward reducing pollution from sewage and organic wastes in Maine. However, untreated municipal wastes, organic industrial effluents, and domestic sewage wastes from individual homes are still a serious problem in some coastal areas. Potential effects on human health and marine organisms as well as current laws and regulations make it necessary to thoroughly investigate the environmental and legal consequences whenever such pollution may occur.

In terms of human health, the primary threat is from the dangerous diseases that are associated with untreated sewage. Sewage pollution also has effects on Maine's economy. In an area where untreated wastes are substantial, commercial and recreational clamming must often be prohibited due to the threat of disease. Currently, about one-fifth of all Maine clam flats are closed to harvesting due to sewage contamination.

One possible impact of sewage disposal and organic pollution on intertidal organisms is excessive nutrient enrichment of the water column. This can result in heavy "blooms" of planktonic plants and algae. As these plants grow and decompose, the level of dissolved oxygen in water can fall drastically, causing die-offs of fish and other species. Serious lack of oxygen can also result as bacteria decompose human wastes, pulp and paper mill wastes, and other organic wastes that may be dumped in the intertidal zone. When the bacteria biodegrade these wastes, they use up substantial amounts of the dissolved oxygen in the water. As in the case of algal blooms, this can harm or kill fish, marine invertebrates and other aquatic organisms. Furthermore, in the area near a sewage or industrial outfall, wastes may sometimes be great enough to actually smother plants and animals living on the bottom sediments.

Ironically, treatment of sewage wastes may sometimes create the potential for other problems. For example, many municipal and individual sewage treatment processes use chlorine to kill disease — causing bacteria. But chlorine is very toxic to many organisms other than bacteria and improper management of chlorine treatment has occasionally resulted in major fish kills. It is possible that chlorine treatment may have impacts on other marine organisms as well, though at present little is known about these effects.

The effluent from sewage treatment plants may also contain oil and other hydrocarbons, toxic chemicals and heavy metals, since most existing treatment plants lack the technology to remove such pollutants. These pollutants normally pass through the plant unaltered into the environment and may have adverse impacts on the species in and near the discharge area. Similarly, the outflow from storm sewers can have effects on intertidal organisms. These sewers carry rain water and meltwater from roads and parking lots either into treatment plants or directly into a nearby body of water. Frequently, the runoff is not as pure as the driven snow or rain that it once was. In passing over roads, parking lots, and other developed acreage, the water may carry with it silt, oil and various toxic chemicals.

FIGURE 7. The sand beach at Reid State Park, Georgetown.

CHAPTER 3

MAINE'S INTERTIDAL ENVIRONMENTS

A Closer Look

Within Maine's 4,000 mile-long intertidal zone, there are a number of unique communities of plants and animals, each adapted to the physical conditions of different kinds of habitats. A sand beach is home to a collection of animals far different than those in a salt marsh. To understand the effects of human activities on intertidal organisms it is necessary to know something about the environmental characteristics of each basic type of intertidal habitat.

As explained in the companion volume to this handbook, *Geology of Maine's Coast,* it is also important to understand that coastal environments are often linked together as part of complex geological systems and that changes in one environment can have impacts on others nearby. In the *Geology of Maine's Coast,* the Maine shoreline is described from a geological perspective based on the 55 types of geologic environments catalogued on the Coastal Marine Geologic Environments Maps developed by Maine's Coastal Program.

These maps are not difficult to understand. In a number of ways, they are similar to the Soil Conservation Service soil maps with which most land use planners are already familiar.

Soils maps are often used in regional or town planning for purposes such as locating areas suitable for subsurface sewage disposal or sanitary landfill sites and for identifying prime agricultural land. The Marine Environments maps can also be helpful for this kind of generalized planning. In addition, because of their larger scale they can be used for more detailed planning and environment impact assessment.

Basically, the Marine Environments maps indicate the size and location of individual geological environments, or "units", (a beach, a mudflat, a tidal channel, etc.) as they occur along the Maine coast. Altogether 109 maps have been produced, covering land along the state's entire coastline between the nearshore uplands and shallow subtidal depths. On them, 55 different types of marine environments are distinguished with simple letter codes.

To coastal residents, the most fundamental use of the maps is to determine the geological characteristics of particular sites in their town. Though verification by on-site inspection should always precede any important decision, a quick look at the appropriate map will show in advance, with reasonable accuracy, what kind

FIGURE 8. Marine Geologic Environment Map and Legend

MAP SYMBOL	GEOLOGIC ENVIRONMENT
	SUPRATIDAL ENVIRONMENTS
Sd	Dunes & Vegetated Beach Ridges
Sw	Fresh-Brackish Water
Sm	Fresh-Brackish Marsh
Sz	Man-Made Land
Sx	Landslide Excavation & Deposits
	INTERTIDAL ENVIRONMENTS
	Marsh Environments
M1	High Salt Marsh
M2	Low Salt Marsh
M3	Marsh Levee
M4	Salt Pannes & Salt Ponds
	Beaches
B1	Sand Beach
B2	Mixed Sand & Gravel Beach
B3	Gravel Beach
B4	Boulder Beach
B5	Low-Energy Beach
Br	Boulder Ramps
Bw	Washover Fan
Bs	Spits
	Flat Environments
F	Mud Flats
F1	Coarse-Grained Flat
F2	Seaweed-Covered Coarse Flat
F3	Mussel Bar
F4	Channel Levee
F5	Algal Flats
F6	Veneered Ramp
	Miscellaneous Environments
M	Ledge
Mc	Fluvial-Estuarine Channel
Mp	Point or Lateral Bars
Ms	Swash Bars
Mf	Flood-Tidal Delta
Me	Ebb-Tidal Delta
Mb	Fan Delta
Md	Spillover Lobe
	SUBTIDAL ENVIRONMENTS
	Flat Environments
Fm	Mud Flat
Fc	Coarse-Grained Flat
Fe	Eelgrass Flat
Fs	Seaweed Community
Fb	Upper Shoreface
Fp	Lower Shoreface
	Channel Environments
C1	High-Velocity Tidal Channel
C2	Medium-Velocity Tidal Channel
C3	Low-Velocity Tidal Channel
C4	Estuarine Channel
C5	Estuarine Flood Channel
C6	Estuarine Ebb Channel
C7	Inlet Channel
C8	Dredged Channel
Cs	Channel Slope

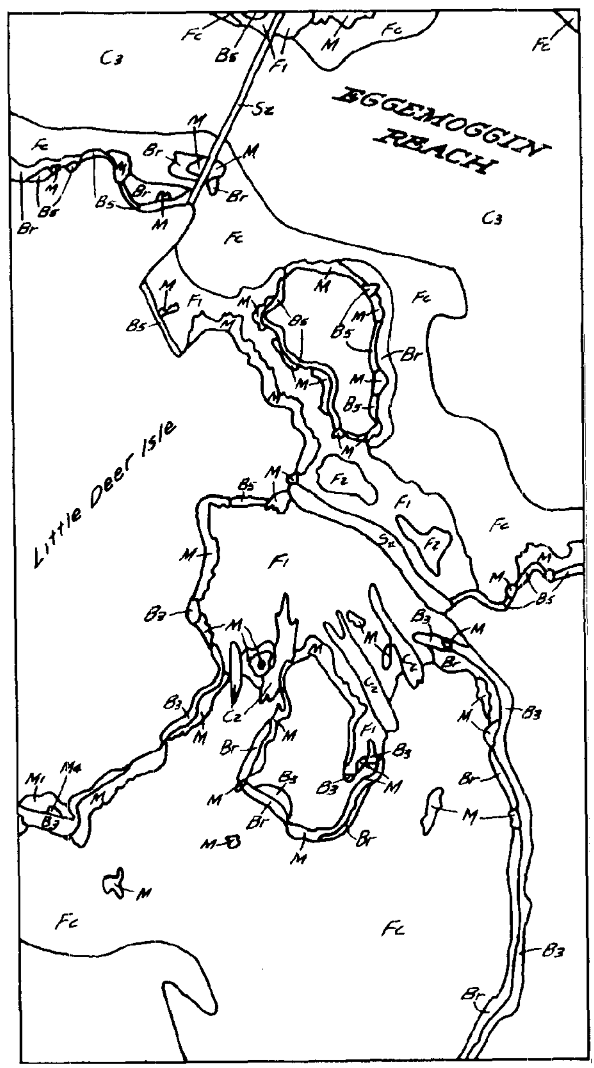
Tidal Creeks

Marsh Drainage Ditch

Unit Boundary

Approximate Unit Boundary

Approximate Transition Boundary Between Estuarine and Marine (30 ppt salinity) Waters and between Estuarine and River (0.5 ppt salinity) Waters.



of environment exists at any given spot in the shoreland zone. It will show, for example, whether a certain intertidal area is a "coarse-grained mudflat" or a "seaweed covered flat".

The pinpointing and identification of these distinct environments is especially advantageous to developers, town planners, industrial researchers, and other people for resource utilization planning. For instance, by using the maps, efforts to locate suitable sites for piers, houses, commercial facilities, industrial plants and other developments are made much easier. Places where unstable soils or other geological conditions make a project unfeasible can be quickly identified and ruled out. The proximity of sensitive, ecologically valuable environments to a site can be noted. In addition, the possibilities for expanding a project in the future can be estimated by looking at the locations, sizes, and nature of the environments in the area.

Similarly, the detailed information on the Marine Environments maps can facilitate the location of potential aquaculture sites, commercially harvestable mussel or seaweed beds, and other marine resources. It can help in creating effective strategies to combat shoreline erosion problems, or in the development of zoning guidelines. Recently, the maps have been used to help formulate the clean-up plans that would be implemented in case of a major oil spill off Maine's coast.

Because the differences between individual sites are also crucial in determining the effects an activity or project may have on the environment, another basic use of these maps is for environmental impact assessment. While in many cases professional advice is needed to undertake this type of analysis, it is possible — and often necessary — for laymen to make judgements about potential environmental impacts for themselves.

Members of municipal planning boards, for example, spend considerable time reviewing developments proposed for their towns, a process that usually involves some kind of environmental impact assessment. For their part, developers generally have to study and report the potential environmental effects of their projects in order to get needed permits and fulfill application requirements.

As a rule, the sophistication of impact assessments varies with the size or expected environmental influence of the project in question, ranging from simple common sense judgements to highly involved computerized simulations and technical studies. Any type of impact assessment, however, should take into consideration the fact that the connections between human activities and marine environments are extremely complex and that the links between the living and non-living components of those environments are equally intricate.

The purpose of this chapter is to expand on the information found in the *Geology of Maine's Coast* handbook and enhance the usefulness of the Marine Environments maps by providing ecological descriptions of individual intertidal habitats. Using this information and the appropriate maps, planners and developers can get a good general idea of what species might be living in a particular intertidal location. Knowing this, they can then draw some preliminary conclusions about the potential biological impacts of a project or activity proposed for that location. It is necessary to remember that these conclusions would be approximations. There is no substitute for actual on-site studies. Nonetheless, they can be extremely helpful and may save considerable time during the early planning stages and preliminary evaluation of coastal projects.

To provide reliable information about Maine's intertidal habitats, extensive studies have been undertaken by researchers from the Bigelow Laboratory for Ocean Sciences, headquartered at McKown Point in West Boothbay Harbor. These researchers carefully analyzed the kinds, numbers, and diversity of species found at sampling sites located in various intertidal habitats up and down the coast.

For purposes of study, the researchers defined nine basic intertidal habitats common to Maine. Because they used an ecological, rather than a geological viewpoint, these habitats are not quite the same as the units defined on the Marine Environments maps and the companion geology handbook. However, there is a very close correlation and the relationships of the two systems of classification are indicated in the following section to allow coordinated use of all three information resources.

Sand Beach Habitats

Description: Sand beach habitats are made up primarily of well sorted, sand-sized particles. They are generally high-energy environments, greatly exposed to the battering of waves. The degree of exposure for a particular sand beach depends on the direction the beach is facing and how much protection is provided by nearby islands, headlands, or other features of the local topography. Most of Maine's relatively limited extent of sand beaches occurs in the area between Kittery and Cape Elizabeth. This so-called Arcuate Bay region is characterized by long stretches of sand beach separated by rocky promontories. East of Cape Elizabeth, sand beaches are much more scarce. Major beaches are found east of Casco Bay at Reid State Park and Popham. There are also numerous small pocket and barrier beaches scattered among islands and peninsulas along the eastern portion of our coast. Well known examples are Sand Beach in Acadia National Park and the beach at Roque Bluffs State Park.

Biological Characteristics: The constant movement of the particles on sand beaches which results from exposure to heavy wave action allows only very specialized intertidal creatures to live in these habitats. In fact, studies indicate that, in an area of a given size, the number of different species and the total number of individual resident organisms is usually lower on sand beaches than any other basic type of intertidal habitat. This is an indication that sand beaches are harsh environments in which to live. The sand grains are continually being shifted by waves, and there is no solid substrate suitable for the attachment of animals or plants. Thus, any sand-dwelling organism must be able to shift or reestablish its "home" frequently.

There are some species that have adapted to this disruptive style of life. Most common and abundant are amphipods, the shrimplike crustaceans known to many beach-goers as "beach fleas". Also relatively abundant on sand beaches are various kinds of burrowing marine worms. various kinds of burrowing marine worms. Other species commonly found on sand beaches include various marine isopods and certain insect larvae and adults.

Importance: Because there are relatively low concentrations of sand worms and other commercially valuable intertidal species on sand beaches, these habitats have relatively low direct economic importance to Maine's marine fisheries industry. Storms do sometimes wash surf clams to lower beach areas in Southern Maine and these are occasionally harvested. However, sand beaches are very valuable and popular for their recreational potential. In addition, sanderlings, sand pipers and many other shorebirds depend on beach amphipods as a major food source.

Planning Considerations: Foot traffic, surf fishing, swimming, sand castle building and most other common activities of beach-goers have little effect on sand beaches. On the other hand, pollution by oil or toxic wastes can have major adverse impacts on beach animals. So, too, can construction on or near a beach.

In terms of planning considerations, it is extremely important to remember that beaches are part of interconnected beach systems, which usually include dunes on the landward side and sand flats on the seaward margins. Alterations of the other parts of this system can affect the beaches as well.

Immediately behind sand beaches, where there are sand dune areas, residential or commercial development can disrupt the natural cyclical transport of sand between beaches and dunes, thus threatening the whole system with sediment "starvation". Devegetation and subsequent erosion of adjacent dune fields can also contribute to any erosion problems occurring on nearby sand beaches. Stocks of sand eroded from the dunes may be lost permanently from the whole beach system.

Seawalls or other shoreline structures built to protect beachfront property are sometimes a threat to beach habitats. Such structures often accelerate erosion on beaches by causing excessive wave scouring, or removal of sand, from in front of the seawalls during storms. Seawalls also tend to increase loss of sediments from adjacent areas at ends of the structures.

Beaches that depend upon riverborne sediments as a source of sand may be adversely impacted by structures such as jetties or upstream dams which divert or retain critical sand supplies into new locations.

Structures located directly in the intertidal area can prevent the transport of sand by waves, tides and currents between offshore deposits and beaches. This contributes to loss of beach habitat by diminishing the natural replenishment of sand during the beach system's annual cycle.

An important consideration with respect to sand beach system is their tendency to migrate landward over time. Beaches are very mobile environments and their location along the shoreline is largely controlled by sea levels. Since the last great Ice Age, sea levels in Maine and worldwide have been rising steadily. This rise "pushes" sand beaches and the dunes behind them gradually inland. The rate of this retreat varies greatly along our coast depending on such factors as shoreline slope, shoreline configuration, and general location of the coastline. Some level of shoreline recession is inevitable on all beach systems, however, and any buildings or other developments on or near beaches should be located a considerable distance behind the current high water mark to prevent future flood or storm damage.

Recent state and federal regulations have increasingly restricted development along beaches. State and federal agencies have also determined rates of shoreline recession for various local areas of our coastline. This information and other government construction guidelines can help planners and developers design and locate projects near beaches appropriately.

Geological Units Included:

SAND BEACHES
Map Legend — B 1
Color — Lemon Yellow
Percentage of Total Cost Area Mapped — 1.00%

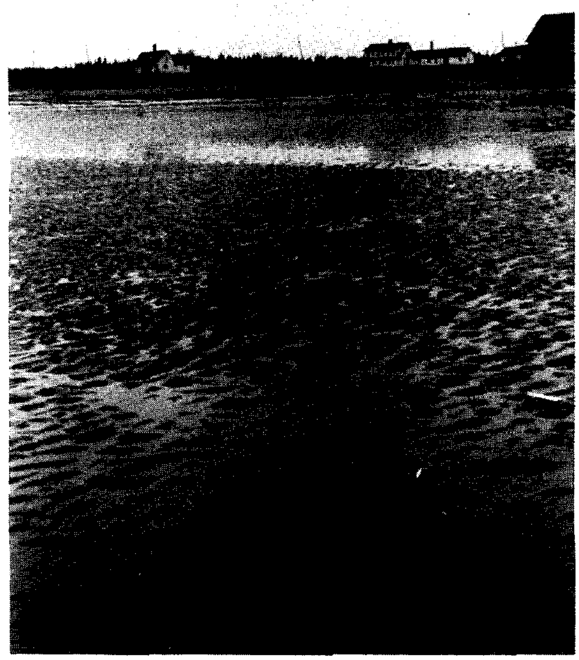
SPITS
Map Legend — B s
Color — Gold
Percentage of Total Coast Area Mapped — 0.04%

MIXED SAND AND GRAVEL BEACHES (in part)
Map Legend — B2
Color — Yellow Orange
Percentage of Total Coast Area Mapped — 1.50%

Sand Flat Habitats

Description: Sand flats might be viewed as the low-energy counterpart of sand beaches. Though composed primarily of sand, these habitats are located in areas more protected from wave exposure than sand beaches. Thus, they have a greater diversity of sediment particle types, including various percentages of silt, clay and organic detritus. These habitats generally have a slight slope and can be distinguished from mud flats by particle composition and the sand ripples generally exhibited on their surfaces. Although low-energy intertidal flats south of Maine are commonly composed of sand, the number of large sand flats in this state is rather limited. Here, particularly east of Cape Elizabeth, most of the source material for low-energy environments is silt and clay, which results in the extensive mud flats found along our coast. The major sand flat areas in Maine are at Sagadahoc Bay and Heal Eddy in Georgetown, Gerrish Island in Kittery, Bailey's Mistake in Trescott and Clam Cove in Rockport. Other less extensive areas of sand flats occur behind some beaches where small streams empty into the ocean. Such places are found at the southern end of Reid State Park, and behind Wells Beach, Thompson Point Beach, Old Orchard Beach and Ogunquit Beach. Often, the upland extent of these small sand flats is salt marsh.

FIGURE 9. A large sand flat at the head of Bailey's Mistake in Trescott.



Biological Characteristics: Because they are protected from heavy wave exposure by local topography, sand flats are much less harsh as environments than sand beaches. This allows a greater variety of animals to live in these habitats. In fact, the diversity of species of sand flats is second only to that on mud flats. However, like sand beaches, the total productivity of sand flats is rather low in terms of the number of individual organisms found per square meter. Various types of marine worms and amphipod crustaceans make up the most abundant groups of species that live on sand flats. Soft-shelled clams are usually fairly common. In areas where the flat is composed of large percentages of silt, the Baltic clam and other species more typical of mud flats may also be common. Moon snails, green crabs and other clam predators are often found on sand flats where their food supply exists.

Importance: Though not as productive as mud flats, sand flats do provide significant habitat for clams, marine worms and other commercially havested species. Resident species also comprise a food source as well as for various species of waterfowl and shorebirds.

Planning Considerations: Most animal residents in sand flats are highly sensitive to pollution by oil and toxic chemicals. Sand flat communities may also be destroyed or harmed by dredging or filling on or near the flats. Among the common impacts that are related to these activities are direct removal of habitat or smothering of habitats by dredge spoil. Dredging, agricultural or construction activities on nearby environments can also release heavy metals or chemicals toxic to sand flat organisms. In addition, the commercial usefulness of sand flats can be destroyed by sewage contamination.

Geological Units Included:

COARSE-GRAINED FLAT (intertidal)
Map Legend — F1
Color — Dark Brown
Percentage of Total Coast Area Mapped — 4.70%

FLOOD TIDAL DELTAS
Map Legend — Mf
Color — Flesh
Percentage of Total Coast Area Mapped — 0.03%

FAN DELTAS
Map Legend — Mb
Color — Tuscan Red
Percentage of Total Coast Area Mapped — 0.01%

CHANNEL LEVEES
Map Legend — F4
Color — Cold Dark Grey
Percentage of Total Coast Area Mapped — 0.01%

SEAWEED-COVERED COARSE-GRAINED FLATS
Map Legend — F2
Color — Light Green
Percentage of Total Coast Area Mapped — 1.00%

EBB-TIDAL DELTAS
Map Legend — Me
Color — Flesh
Percentage of Total Coast Area Mapped — 0.03%

VEGETATED POINT OR LATERAL BARS
Map Legend — My
Color — Dark Green
Percentage of Total Coast Area Mapped — 0.01%

Mud Flat Habitats

Description: Mud flats are fine-grained habitats found in coves, inlets and other protected, low-energy coastal sites. The sediments, which include various proportions of silt, clay, sand and organic material, are relatively stable. Being shielded from heavy wave exposure, they are not greatly shifted or disturbed by wave action or the daily movements of the tides. Mud flats usually have only a very slight grade and are anoxic (lacking in oxygen) just below the surface. These familiar habitats are a dominant intertidal environment along the coast of Maine, in terms of area, and second in linear extent only to rocky shores. In fact, most protected coves, salt marsh borders and other low-energy intertidal areas east of Cape Elizabeth drain to expose mud flats. When one looks at a map of Maine's irregular coastline, it is obvious that there are numerous protected areas likely to harbor mud flats. The mid-coast area between Casco Bay and Port Clyde is particularly irregular. As would be expected, mud flats here are numerous and extensive. Mud flats are also extensive down east in Hancock and Washington counties, where the large tidal ranges often create flats of great width.

Biological Characteristics: Biologically, mud flats are one of the most productive coastal habitats. The diversity of species is higher than in any other intertidal habitat. The average number of organisms found per square meter is phenomenal. (Only boulder beaches and high-energy rocky shores host more.) At some mud flat research sampling stations, over 24,000 marine worms, 23,000 gem clams, and 16,000 Hydrobia snails were found in one square meter of the rich mud. Marine worms and many other common mud flat animals are relatively sedentary, often living in tube houses in the mud, feeding mainly on organic detritus. This is called deposit feeding. Other common residents of mud flats, such as soft shelled clams, feed on small plants (phytoplankton) and animals (zooplankton) they filter out of the water column. This is called suspension or filter feeding. Among the most abundant species found in mud flats are various types of marine worms (including the valuable bait species called bloodworms and sand worms), soft shelled clams, Baltic clams, gem clams, mud snails and other gastropods, and various small amphipods (mud dwelling relatives of the "sand fleas" found on beaches).

Here and there on mud flats, one often finds mussel bars, dense accumulations of blue mussels which form a sort of living reef. The number of mussel bars on a flat tends to vary from year to year due to frequent destruction by storm waves or ice. When severe storms hit Maine, there may be a significant, though temporary, reduction in the total number of mussel bars along the entire coast. During periods when water temperatures are warm and wave action slight, mussell bar formation is stimulated.

Importance: Mud flats are highly productive both biologically and economically. Each year the harvesting of soft shelled clams, bloodworms, sand worms, and other species brings tens of millions of dollars to Maine's economy and employs hundreds of people. Many kinds of valuable fish species, including winter flounder, depend on mud flats as feeding habitats. Other common consumers of mud flat animals include black ducks, loons and other waterfowl, sandpipers and other small shorebirds, blue herons and snowy egrets.

Planning Considerations: Mud flats are the most sensitive of all Maine's intertidal habitats to disturbance caused by man. Industrial effluent, sewage and other wastes discharged or dumped on or near a mud flat may drastically reduce the flat's productivity and commercial usefulness. Even "clean" water discharged by shoreline industrial plants can reduce a flat's productivity and diversity if the temperature of the water is significantly higher or lower then that of the ocean (this is called thermal loading). Oil spills can wipe out virtually all species living in a mud flat. And, because the muddy substrate this habitat is very stable and scarcely flushed by water, oil can remain in the sediments for many years, making the reestablishment of a normally diverse mud flat community impossible for a long period of time.

A potential threat to mud flats is excessive harvesting of clams and marine worms. Digging activities disrupt the orientation, depth and "homes" of young clams and other mud-dwelling species and exposes these animals to harsh weather extremes and predators. Digging during cold winter days is particularly disruptive, since exposure of a cold-blooded animal to freezing temperatures is often quickly lethal.

Mud flat habitats may also be disturbed or destroyed by dredging or filling on the flats or on nearby environments. Dredging flats or dumping a smothering load of dredge spoil on them can reduce productivity for years. Dredging of adjacent wetlands or agricultural activities and construction on nearby uplands can release an unnatural influx of sediments that may smother shellfish beds and introduce into the water heavy metals and chemicals that are toxic to clams, marine worms and other mud flat species.

Geological Units included:

MUD FLATS (Intertidal)
Map Legend — F
Color — Dark Brown
Percentage of Total Coast Area Mapped — 27.00%

ALGAL FLATS
Map Legend — F5
Color — Green Bice
Percentage of Total Coast Area Mapped — 0.08%

MUSSEL BAR (in part)
Map Legend — F3
Color — Scarlet Red
Percentage of Total Coast Area Mapped — 0.04%

Gravel Beach Habitats

Description: Gravel Beach habitats are relatively stable, course-grained sedimentary environments characterized by good percolation which results in a deep anoxic (oxygen-free) layer well below the sediment surface. (It should be noted that the geologic units called "gravel beaches" on the Marine Environments Maps are called "cobble beaches" in this handbook; moreover, gravel beach habitats in this handbook include the geologic environments referred to as "low-energy beaches" and "mixed sand and gravel beaches" on the Marine Environments Maps.) Beaches composed of gravel in a strict geologic sense are rare in Maine. Most gravel beach habitats are gravel-sand or gravel-cobble combinations. These habitats occur in coves and other sheltered areas along the shoreline. Gravel, or gravel-sand, is often present at the inner, low-energy portions of coves. Seaward of these inner portions, gravel generally gives way to cobbles, then to boulders, and then (though not always) to bedrock. This graduation of sediment types is a result of the increasing energy levels, or wave action, noted from the inner cove to the exposed point. However, while gravel beaches are considered low-energy environments, the energy levels affecting them may still be much higher than those affecting mud or sand flats. The best examples of gravel beach-to-cobble graduation are found in Penobscot Bay and, to a lesser extent, in Cobscook Bay. In other areas, such as Kittery, Bailey Island and Perry, the intertidal zone of coves also commonly grades from gravel to cobble, but the geologic and energy structures tend to be more complex.

Biological Characteristics: Gravel beaches are relatively harsh environments. Though not as harsh as a sand beach, where high wave exposure is constantly shifting the sand, gravel is also moved by waves. This makes it difficult for many attached species, including algae, to become established in any abundance, or, in some cases, to survive at all. As a result, the diversity of species on gravel beaches is very low. In fact, species diversity is lower only on sand beaches. Nonetheless, some species are adapted to making their home in the relatively stable environment under the shifting upper layer of surface gravel. The most abundant species are various types of burrowing marine worms. Less abundant but not uncommon are snails, barnacles, and clams.

Importance: Most gravel beaches are rarely used for either recreational purposes or commercial harvesting of clams and marine worms and thus provide little direct economic benefits to Maine. However, the predominance of marine worms in these environments make them indirectly valuable as feeding habitats for flounder and other important commercial fish species.

Planning Considerations: Like sand beaches, gravel beaches are often subject to gradual landward migration as a result of sea level rise, though they are less mobile than beach-dune systems. Thus, development should be set back a reasonable distance (determined by on-site evaluation).

Geological Units Included:

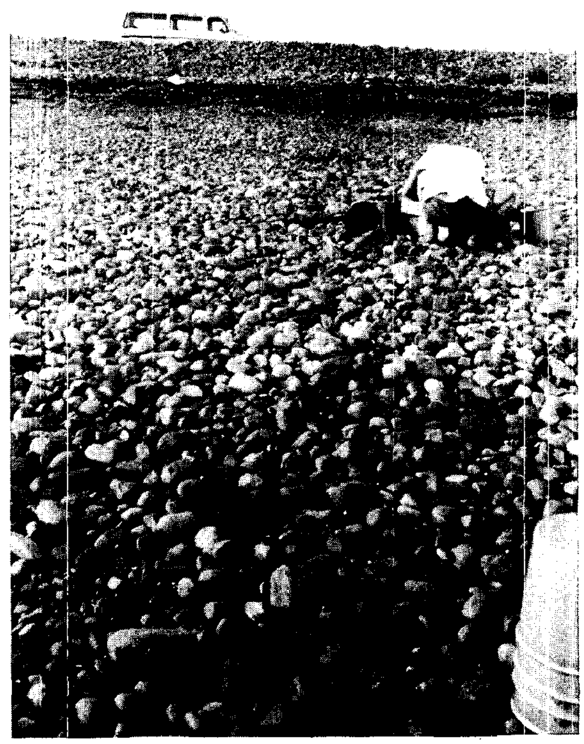
MUSSEL BAR (in part)
Map Legend — F3
Color — Scarlet Red
Percentage of Total Coast Area Mapped — 0.04%

LOW ENERGY BEACHES
Map Legend — B5
Color — Magenta
Percentage of Total Coast Area Mapped — 4.00%

Cobble Beach Habitats

Description: These habitats (called gravel beaches on the marine environments maps) are made up of rocks large enough to be used as a substrate for attachment by marine organisms who dwell on rock surfaces, but small enough to be moved easily by heavy waves. Since cobbles are larger and heavier than gravel, they are found in locations where wave exposure, or energy levels, are somewhat higher. Frequently, cobble beaches are found next to gravel beaches in coves, just seaward of the gravel habitat. Good examples of this association exist in Penobscot and Cobscook Bays, and at Bailey Island, Perry and Kittery. As in gravel beach areas, the sediments under the surface of cobble beaches consists of a mixture of sand and gravel. During storms, heavy waves often throw rocks from cobble beaches into the upper intertidal zone, where they form low ridges. This unquestionably wreaks great havoc on the animals living on the cobbles.

FIGURE 10. Looking up a transect on a cobble beach at Kennebunkport.



Biological Characteristics: Although cobbles are moved by wave action, they do not move as readily as gravel and the surface is thus more stable than on gravel beaches. This allows a greater number and variety of organisms to survive. However, while species diversity and the abundance of individual organisms on cobble beaches is greater than noted for gravel or sand beaches, numbers for both factors are still relatively low compared to other intertidal environments. Common resident species include various marine worms, isopods (small ocean dwelling relatives of the mill-bugs or sow-bugs found in gardens and under forest leaf litter), barnacles, periwinkle snails, and blue mussels. Some soft-shelled clams and other bivalves dwell in the sandy substrate beneath the cobbles.

Importance: Like gravel beaches, cobble beaches provide little direct economic benefits to Maine but do provide feeding habitat for flounder and other valuable fish species. This indirect importance is probably somewhat more significant than that of gravel beaches since the abundance of small marine organisms is greater.

Planning Considerations: Cobble beaches are generally unsuitable, and rarely used for, any type of development. Occasionally, roads are built behind the storm ridges. However, because cobble beaches are subject to landward recession due to the steady rise of world sea level, washovers resulting from wave action often necessitates constant repair of these roads. Thus, in general, roads or any other construction should usually be set back from cobble beaches and their storm ridges far enough to avoid such problems.

Geologic Units Included:

GRAVEL BEACHES
Map Legend — B3
Color — Non-photo Blue
Percentage of Total Coast Area Mapped — 3.00%

Boulder Beach Habitats

Description: Boulder beaches are composed of large rocks that are generally moved only by severe storm waves. Tide pools and pockets of finer sediments are common within these habitats between and beneath the boulders. Boulder beaches occur at a number of locations along the Maine Coast. In Penobscot Bay, they are often the high energy points of land on the outer margins of coves. In other areas of the state, they are found next to bedrock promontories where energy levels are slightly lower. (A good example is at Mount Desert's Otter Point area, where the bedrock cliffs give way to a boulder beach that becomes a cobble-gravel beach at the head of the cove.)

Biological Characteristics: On most boulder beaches, growths of attached algae, or seaweed, are present. This alone makes boulder beaches significantly different from algae-free cobble and gravel habitats. The boulders are also large and stable enough to provide a suitable substrate for many attached animal species. In addition, the areas between the boulders provides shelter for a variety of organisms and the sediment beneath and between provides habitat for many types of burrowing creatures. As a result, species diversity and the number of individual organisms per square meter on boulder beaches is relatively high (though not as great as noted for mud flats and high-energy rocky shores). The most abundant resident species are marine worms, barnacles, blue mussels and periwinkle snails. Starfish, green crabs, amphipods and isopods are common here. Sea cucumbers, brittle stars, sea spiders and other interesting intertidal creatures may also be found. It is noteworthy that many of the species that reside on boulder beaches are creatures commonly found in rocky shore habitats (a few are found only on boulder beaches or rocky shores).

Importance: A direct economic benefit provided by some boulder beaches is from the occasional commercial harvesting of the dense growths of the rockweed, *Ascophyllum* (processed to provide food additives and micronutrients for livestock and crops). However, the relative abundance of small marine creatures gives all boulder beaches indirect significance as feeding areas for commercial fish species and other creatures higher on the food chain. Many people also appreciate the aesthetic characteristics of boulder beaches, particularly the beauty of the ocean-polished boulders and the sound they make when impacted by waves.

Planning Considerations: Boulder beaches are generally considered poor sites for construction of shore facilities or other developments.

Geologic Units Included:

BOULDER BEACHES
Map Legend — B3
Color — Non-photo Blue
Percentage of Total Coast Area Mapped — 0.5%

BOULDER RAMPS
Map Legend — Br
Color — Non-photo Blue
Percentage of Total Coast Area Mapped — 2.00%

High-energy Rocky Shore Habitats

Description: These habitats are composed of bedrock ledge located in relatively exposed areas of the shoreline, where heavy wave action significantly affects intertidal zonation. Tide pools are often present and are here considered a part of this habitat type. Much of Maine's coast east of Cape Elizabeth is characterized by high-energy rocky shores. The highest-energy areas are at headlands, such as Two Lights at Cape Elizabeth, Pemaquid Point, or Quoddy Head in Lubec.

Biological Characteristics: The biological communities living on high-energy rocky shores consists of organisms living on rock surfaces. At any levels on the rocky shore the dominance of species is largely controlled by the degree of exposure to waves and biological interactions. These habitats usually have four distinct layers or zones. The uppermost, or high intertidal zone, is the harshest. Only a few species are found in this zone (primarily tiny forms of algae, periwinkles and small insects called springtails). The other three zones host an increasingly diverse variety of species. Moreover, the numbers of individual organisms per square meter is execptionally high, far more than any other type of intertidal habitat. Below the high intertidal zone on the rocky shore lies the barnacle zone, dominated by dense populations of barnacles and blue mussels. Also common in this zone are small amphipods and marine worms. Below is the rockweed zone, noted by dense growths of rockweed, large marine algae and an abundance of periwinkles. Other common residents of the rockweed zone include dog whelks, limpets, blue mussels, horse mussels and rock barnacles. The lowest layer of high-energy rocky shores is called the Chondrus zone, named for the dense growths of Irish Moss (*Chondrus crispus*) found here. Among the most common animal residents of this zone are green sponges, limpets, periwinkles, baltic clams, amphipods, green crabs and starfish. Other species commonly found here include various anemones and nudibranchs (shell-less relatives of the snail), rock crabs, blood starfish, brittle stars and sea urchins.

Importance: Direct economic benefits result from the harvesting of rockweed and Irish moss, blue mussels and periwinkles from some high-energy rocky shores. Also significant are the aesthetic and educational values of these interesting and productive habitats. Ledge outcrops, which may also be isolated from the mainland as islands, provide feeding and breeding habitat for many eider ducks, black ducks and other waterfowl, for various species of seabirds, and for harbor seals.

Planning Considerations: Rocky shoreline areas that are not significant breeding areas for birds and seals are some of the best sites for shoreline construction and development (excluding conventional septic systems), since they are both solid and rarely prone to erosion problems. They also offer opportunities for harvesting of mussels and seaweeds, which are commercially important in some areas. One potential threat to ledge-dwelling species is an increased influx of sediments, sometimes caused by agricultural activities or construction on nearby uplands. Such increases in sediment load may smother productive ledge habitats, a problem which can also develop when man-made construction along the shoreline alters current and wave patterns. Contamination by oil or toxic chemicals can also reduce the productivity of ledge environments and their suitability as habitat for birds and seals.

Occasionally, foot traffic, or the collecting or havesting of mussels, seaweed and other species may become excessive on a popular stretch of rocky shore. In such cases, some limitating of these activities may be necessary to prevent localized reductions in species diversity or to preserve aesthetic qualities or special natural areas.

Geologic Units Included:

LEDGE (in part)
Map Legend — M
Color — Warm Light Grey
Percentage of Total Coast Area Mapped — 12.00%

Low-energy Rocky Shore Habitats

Description: These are habitats composed of bedrock located in intertidal areas protected from heavy wave action. (Though low-energy rocky shores are ecologically different from high-energy rocky shores, both are referred to collectively as "ledges" on the marine environments maps.) Low-energy rocky shores are often found in coves whose width is narrow enough so that waves cannot build up to any extent and the shore is not exposed to the energy of the open ocean. These are common habitats found in many areas along Maine's irregular coastline. Most low-energy rocky shores studies have a layer of silt coating the surface of the rocks and attached seaweeds.

FIGURE 11. The low-energy rocky shore in East Waldoboro.

Biological Characteristics: Biologically, low-energy rocky shores are moderately productive. The variety of species falls between that of gravel and cobble beaches. The abundance of individual organisms is less than on mud flats, boulder beaches and high-energy rocky shores. Dominant species include rockweeds, barnacles, segmented marine worms, periwinkles and blue mussels. Other common residents include green crabs, isopods and limpets.

Importance: Similar to that described for high-energy rocky shores.

Planning Considerations: Similar to those listed for high-energy rocky shores.

Geological Units Included:

LEDGE (in part)
Map Legend — M
Color — Dark Brown
Percentage of Total Coast Area Mapped — 12.00%

VENEERED RAMP
Map Legend — F6
Color — Dark Brown
Percentage of Total Coast Area Mapped — 0.05%

Salt Marsh Habitats

Description: Salt marshes are dominated by thick stands of marsh grasses, characteristically cord grass *(Spartina alterniflora)* and salt marsh hay *(Spartina patens).* The nutrient-rich substrate in these environments is composed of mud, grass roots and peat (the decomposed remains of marsh plants). Maine has a relatively limited amount of salt marsh along its coast, comprising only about 5 percent of the total shoreline zone. Most of these marsh lands are found on the southern and central coast. They range from fringe marsh at the heads of mud flats and estuaries to the broad expanses of marsh often found behind dune-beach systems. For example, the Scarborough Marsh behind Pine Point at the northern end of Old Orchard Beach includes about 20 percent of Maine's total salt marsh area.

Biological Characteristics: Salt marshes are ecologically rich environments, with relatively high numbers of individual organisms per square meter. The diversity of resident species is only moderate, but many "transient" species of fish, birds and mammals use marshes as feeding, nesting or nursery habitats. In the mud beneath the dense growths of marsh grasses, burrowing marine worms are particularly abundant. Other common resident species include amphipods, snails, ribbed mussels and soft-shelled clams. Crabs and juvenile fishes of various species frequently live in the tidal streams running through salt marshes.

Importance: Salt marshes, once viewed as useless, mosquito-breeding wastelands, are now generally considered one of our most valuable intertidal habitats. The rich organic detritus flushed from marshes by the tides provide crucial nutrients upon which many oceanic food chains are based. Many species important to Maine's commercial fisheries live, feed, or spend their early life stages in salt marsh habitats. Ospreys, bald eagles, various shorebirds and waterfowl and numerous colorful songbirds feed or nest in marsh areas. Beyond their significant function as wildlife habitats, marshes temporarily store flood waters, thus reducing the severity of coastal flooding. Wide bands of marsh land in front of upland shores absorb the brunt of heavy storm waves, thus protecting the mainland from severe erosion and property damage. In addition, the dense marsh vegetation often captures and holds pollutants and sediments that could otherwise run off into shellfish beds and navigational channels.

Planning Considerations: Salt marshes are very sensitive to changes in the volume of water flowing into and out of them. Dredging, ditching or filling activities on or near marshes can change the hydrology of these habitats and thus their ecological productivity. Dredging can also release chemicals or heavy metals formerly bound up in the marsh sediments which may be toxic to fish and shellfish. Pollution by pesticides or oil can have similarly adverse effects on marsh organisms. Light or heavy development, roadbuilding and most other types of construction are not considered suitable on marshes, nor is the disposal of solid or liquid wastes. On the whole, the most appropriate activities in these environments are recreational, such as hunting, birdwatching, boating, and canoeing. Occasionally, in areas of heavy use, foot traffic can cause devegetation that may lead to minor erosion problems. Excessive boat traffic may also lead to bank erosion and increased water turbidity along tidal streams.

Geologic Units Included:

HIGH SALT MARSHES
Map Legend — M1
Color — Peacock Green
Percentage of Total Coast Area Mapped — 5.00%

LOW SALT MARSH
Map Legend — M2
Color — Peacock Green
Percentage of Total Coast Area Mapped — 0.10%

MARSH LEVEES
Map Legend — M3
Color — Peacock Green
Percentage of Total Coast Area Mapped — 0.01%

SALT PANNES AND PONDS
Map Legend — M4
Color — True Blue
Percentage of Total Coast Area Mapped — 0.05%

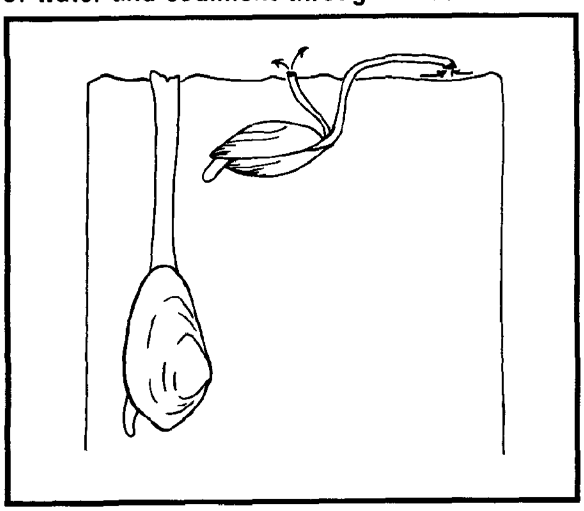
FIGURE 12. The high-energy rocky shore at Cape Neddick.

CHAPTER 4

A SAMPLER OF INTERTIDAL SPECIES

The intertidal zone of Maine is rich in the number of variety of species which inhabit it. Many of the species occur in several habitats over a wide geographic range. Others are quite specific to a given habitat or location. The following section provides brief natural history sketches of some species common to our region.

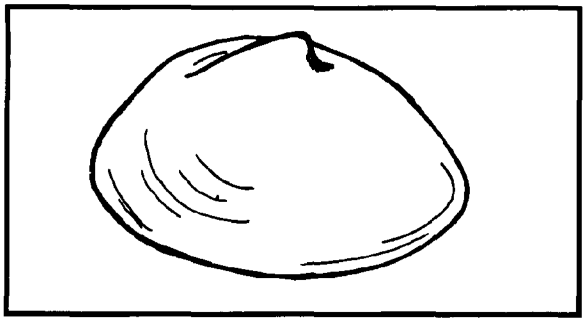
FIGURE 13. Drawing of *Mya arenaria* (left) and *Macoma balthica* showing their relative positions in the sediment. Arrows illustrate the movement of water and sediment through *Macoma*.



Mya arenaria, commonly known as the soft-shelled clam, is an important commercial and recreational species in New England and the Chesapeake Bay. In Maine, this bivalve is generally harvested from mudflats, but it is also abundant on other substrates such as sand or gravel. It may live subtidally in estuaries and can live throughout most of the intertidal zone; however, it reaches its greatest size in the lower intertidal zone, where its feeding period as a filter feeder is maximized. Its food consists primarily of phytoplankton (free-floating unicellular algae).

The spawning season varies along the Maine coast, but lasts generally from May to September. After a two-week planktonic larval stage (which plays an important role in dispersal of the species), the organism settles to the bottom and establishes a permanent burrow. Populations of the soft-shelled clam may reach a density of over 300 per square meter. It's most serious competitor is the blue mussel, *Mytilus edulis,* which can overgrow clam beds. Predators include flounder, ducks, horseshoe crabs, green crabs, and moon snails.

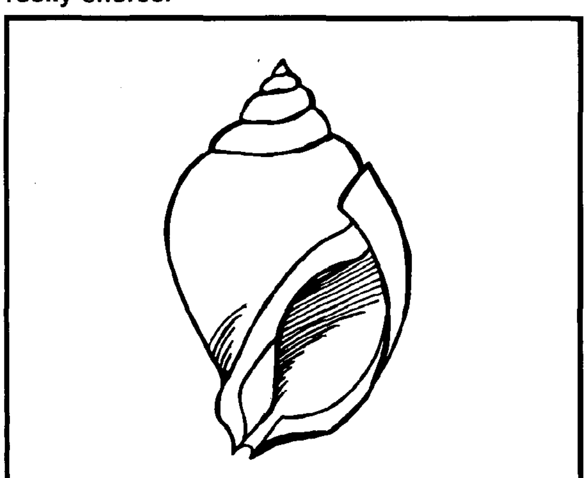
FIGURE 14. The shell of the baltic clam, *Macoma balthica*, a dominant resident of Maine's intertidal zone.



The baltic clam, *Macoma balthica,* is a dominant intertidal species occurring most commonly in mud. In the western Atlantic, its range extends from the Arctic Seas to Georgia, and it occurs throughout the world at similar latitudes. *Macoma* is a deposit feeder, feeding on detritus and bacteria, using its vacuum-like siphon to take sediment from the water-mud interface. Its feces may be recolonized by bacteria and again become a food source for *Macoma* and other deposit feeders.

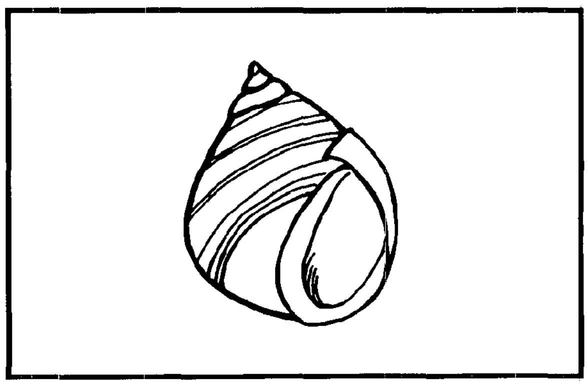
After a 2-5 week planktonic larval stage, the Baltic clam settles to the bottom and changes into an adult. Its primary competitor is the amphipod, *Corophium voluntator,* which not only competes for food, but may often prevent successful settlement of the planktonic larvae, thereby disrupting the development cycle of the clam. *Macoma* is probably eaten by a number of predators. The polychaete worm, *Nephtys,* preys heavily on the larval clams and the adults are eaten by fish and birds.

FIGURE 15. The dog whelk, *Nucella lapillus*, a common predator of barnacles and mussels on rocky shores.



Nucella lapillus, the dog whelk, is a gastropod, or snail, commonly found on rocky substrates in the intertidal zone from Cape Cod to the Bay of Fundy. It is generally white with orange or brown bands, and may reach a length of 30 mm. Spawning may occur at any time of the year, and there is no planktonic larval stage. The larvae hatch looking like miniature adults and move to the lower intertidal zone where they feed on tiny polychaete worms and young mussels. As adults, they inhabit a higher area of the intertidal zone and feed primarily on barnacles and adult mussels by boring directly through the shells of their prey. This species often occurs in dense clusters, especially under rockweeds. *Nucella* is vulnerable to ice and extreme cold, but it may withstand extended exposure to the atomsphere, although not as long as barnacle *Balanus balanoides.* Its chief predators are gulls and sandpipers.

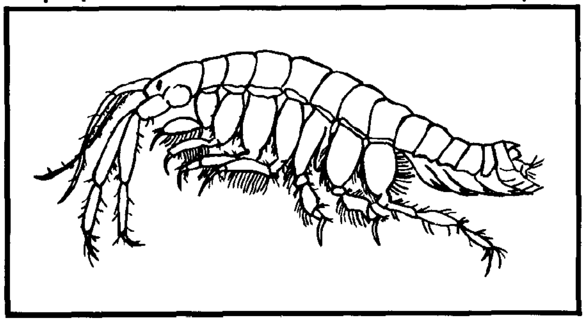
FIGURE 16. The common and widely distributed periwinkle, *Littorina littorea*.



This gastropod species is the common periwinkle, found in great abundance throughout the intertidal zone on both sides of the Atlantic. On the western side, it occurs from Labrador to Maryland. In Maine, it occurs on both rocky shores and mud flats, where it grazes on surface films of algae, algal detritus, diatoms, and lichens.

Spawning takes place in February and March, and the larvae are planktonic until May or June, when they settle and undergo metamorphoses. *Littorina* exhibits a daily pattern of migration, towards land at dusk and sea at dawn. This may be an adaption for withstanding long periods of exposure. Gulls and flounders are its chief predators. Competitors for food and space are numerous and include other molluscs, ascidians, barnacles, hydroids, and sponges.

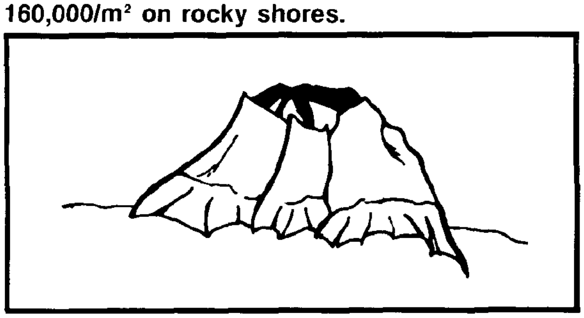
FIGURE 17. *Corophium volutator*, the dominant amphipod of mud flats in Maine and Europe.



Corophium volutator is a tube-dwelling amphipod crustacean found intertidally, especially in estuaries and salt marshes, on both sides of the Atlantic. Its range extends from Norway to the Adriatic and the Bay of Fundy to New Hampshire. It is a dominant species in areas with fine-grained sediment, particularly mud. Population densitites may be as high as 60,000 per square meter. *Corophium* is capable of both deposit feeding (in or out of the burrow) and filter feeding, using its feathery respiratory system.

Breeding season ranges from early to late spring. Fertilization is external and development is direct, i.e. there is no free floating larval stage. The young are brooded by the mother until they resemble small adults, and are then released. Significant predators are shorebirds and flounders. The major competitor is the polychaete worm *Nereis diversicolor*. Frequently *Corophium* is so abundant that it prevents the successful settlement of the larvae of other species, such as the Baltic clam.

FIGURE 18. The rock barnacle, *Balanus balanoides*, which reaches densities of up to 160,000/m^2 on rocky shores.

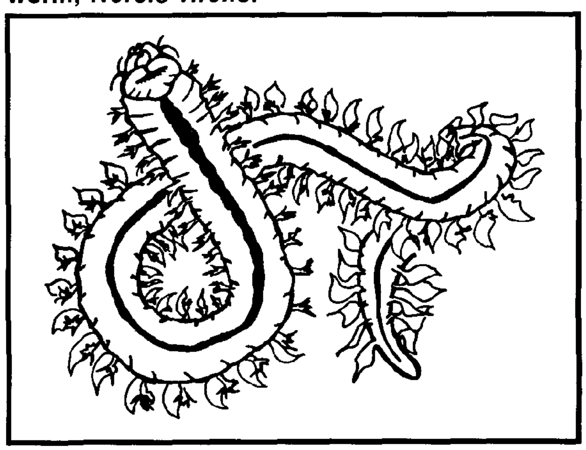


The rock barnacle, *Balanus balanoides*, is found abundantly in the upper intertidal zone from the Arctic to Delaware and on the eastern side of the Atlantic. Though covered with several hard calcareous plates resembling a shell, the barnacle is actually a crustacean like crabs and amphipods. It attaches permanently to hard substrates, such as rocks, pilings, and boat bottoms, and feeds on phytoplankton, selectively filtering certain types from the water. It is resistant to desiccation and is capable of breathing in air; both qualities make it highly adapted to life in the upper intertidal zone.

All barnacles have both male and female sexual organs. They cross-fertilize in the fall and release tiny, shell-less planktonic larvae in late winter or early spring. These larvae comprise a major portion on the plankton during this time of year. Settlement occurs in early summer and is influenced by several factors, including the nature of the substrate and surrounding fauna.

Predators of the barnacle vary with the stage of the life cycle: herring feed on planktonic larvae, periwinkle on newly settled individuals, and dog whelks, crabs, and polychaetes on adults. There is spatial competition within the species and with other species such as blue mussels, rockweed, colonial tunicates and encrusting bryozoa. In Maine, densities of barnacles have been observed up to 160,000 per square meter.

FIGURE 19. The commercially important sand worm, *Nereis virens*.

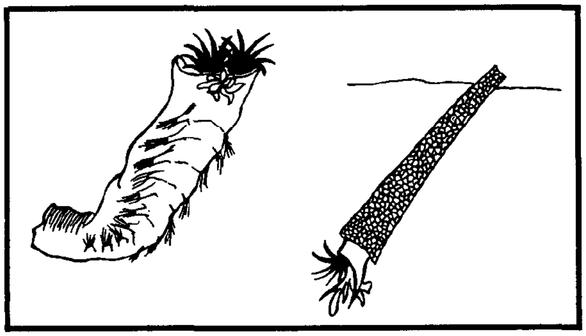


Known as the clam-worm or sandworm, *Nereis virens* is a very common polychaete worm in intertidal mud flats, mussel beds, and occasionally subtidally. It may reach a length of about three feet (1m). This species often leaves its burrow at night to swim and feed. As in the case of many polychaetes, feeding methods of *Nereis* may be variable, depending on food source, and differ between populations. It has been shown to feed on small animals, plants and plankton.

Spawning usually occurs in May, during a new moon, as the worms swarm at the water surface, releasing their eggs.

Nereis virens is an important food source for fish and crabs, and is also a commercially important species in Maine, utilized as bait for sport fishing. This species can withstand a broad range of salinity and has a wide geographic distribution: Norway to France, Iceland, and Newfoundland to Virginia.

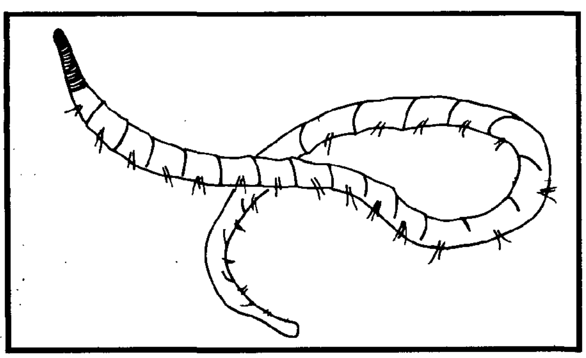
FIGURE 20. The cone worm, *Pectinaria gouldii*, showing both the worm itself and its natural posture in the sediment.



Pectinaria gouldii, the cone worm, is a tube-dwelling polychaete which is often found in soft intertidal and subtidal sediments, especially sand and mud. Its tube is shaped like an ice cream cone which is open at both ends, and it is made of secretion. The worm lives head down in the sediment and is a deposit feeder, stripping the diatoms and detritus from the sediments it ingests.

Knowledge of its reproductive cycle is incomplete. Sexes are separate, fertilization is external, and there is a planktonic larval stage. It is preyed primarily upon by fish.

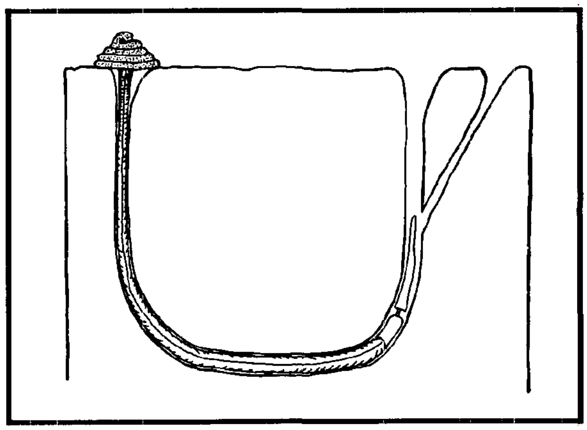
FIGURE 21. An example of one of the species of oligochaetes which are abundant all along the Maine coast.



Oligochaetes are a class of annelid, segmented worms. Various species may be found from the intertidal zone to the deep ocean in sediment, decaying vegetation, and under rocks. They are predominantly burrow-dwellers that feed non-selectively on bottom deposits. Chief competitors are other deposit-feeders, including polychaetes, molluscs, crustaceans, and echinoderms. *Oligochaetes* are undoubtedly preyed upon by several species: chief among them is the winter flounder.

Oligochaetes have both male and female sexual organs and usually undergo cross-fertilization. There is no larval form. In some cases, asexual reproduction by fission may occur. Recent evidence suggests that certain oligochaete species may be important indicators of pollution. Certain populations may become dominant in areas where there is an increase in concentrations of organic matter and decrease in oxygen concentration (for example, in the area of sewage outfall).

FIGURE 22. The acorn worm, *Saccoglossus kowalevski*, in a typical burrow showing a characteristic fecal mass.



Saccoglossus kowalevski, an acorn worm, lives in intertidal and subtidal sand and mud, ranging at least from Maine to North Carolina. It constructs a mucous-lined burrow, open at both ends, from which it extrudes its castings into large piles. It feeds unselectively on the surrounding deposits with its long proboscis. Sexes are separate and fertilization is external. There is no planktonic larval stage. Predators of *Saccoglossus* are not well known, but other species of this group are known to be preyed upon to some extent by crabs and fish.

FIGURE 23. Title 38, §471-478, Alterations of Coastal Wetlands*

§ 471. Prohibitions

No person shall dredge or cause to be dredged, drain or cause to be drained, fill or cause to be filled or erect or cause to be erected a causeway, bridge, marina, wharf, dock or other permanent structure in,on, or over any coastal wetland; or bulldoze, remove, add or displace sand, or build any permanent structure in, on or over any coastal sand dune without first obtaining a permit therefor from the Board of Environmental Protection or a municipality acting under the provisions of section 473 and 474; nor shall any action be taken in violation of the conditions of such permit, once obtained.

§ 472. Definition

As used in the alteration of coastal wetlands law, unless the context otherwise indicates, the following terms shall have the following meanings.

1. **Coastal sand dunes.** "Coastal sand dunes" are sand deposits within a marine beach system above high tide including, but not limited to, beach berms, frontal dune ridges, back dune areas and other sand areas deposited by wave or wind action. Coastal sand dunes may extend into the coastal wetlands.

2. **Coastal wetlands.** "Coastal wetlands" are all tidal and subtidal lands including all areas below any identifiable debris line left by tidal action, all areas with vegetation present that is tolerant of salt water and occurs primarily in a salt water habitat, and any swamp, marsh, bog, beach, flat or other contiguous lowland which is subject to tidal action or normal storm flowage at any time excepting periods of maximum storm activity. Coastal wetlands may include portions of coastal sand dunes.

§ 473. Permit granting authority

All permits shall be issued by the Board of Environmental Protection, except that a municipality may apply, on forms provided by the board, to the Board of Environmental Protection for authority to issue such permits. The board shall grant such authority if it finds that the municipality has:

1. **Planning Board.** Established a planning board;

2. **Adopted zoning ordinance.** Adopted a zoning ordinance approved by the board and the Land Use Regulation Commission, pursuant to Title 12, chapter 424;

3. **Notice.** Made provision by ordinance or regulation for prompt notice to the board and the public upon receipt of application and written notification to the applicant and the board of the issuance of or denial of a permit stating the reasons therefor; and

4. **Application form.** The application form shall be the same as that provided by the Board of Environmental Protection.

In the event that the board finds that a municipality has failed to satisfy one or more of the above listed criteria, it shall notify the municipality accordingly and make recommendations through which it may establish compliance. The municipality may then submit a modified application for approval.

If at any time the board determines that a municipality may be failing to exercise its permit granting authority in accordance with its approval procedures or the purposes of this Article as embodied in the standards set forth in section 474, it shall notify the municipality of the specific alleged deficiencies and shall order a public hearing, of which adequate public notice shall be given, to be held in the municipality to solicit public or official comment thereon. Following such hearing, if it finds such deficiencies, it may revoke the municipality's permit granting authority. The municipality may reapply for authority at any time.

§ 474. Permits; standards

1. **Wetlands permit.** If the applicant for the wetlands permit demonstrates to the satisfaction of the board or municipality as appropriate, that the proposed activity will not unreasonably interfere with existing recreational and navigational uses; nor cause unreasonable soil erosion; nor unreasonably interfere with the natural flow of any waters; nor unreasonably harm wildlife or freshwater, estuarine or marine fisheries; nor lower the quality of any waters, the board of muncipality shall grant the permit upon such terms as are necessary to insure that the proposed activity will comply with the foregoing standards.

In municipalities that have been delegated the authority to issue permits under this Article, within 30 days after receipt of a completed application for a permit, the municipality shall either issue the permit or deny the permit setting forth the reasons therefor or order a hearing thereon within 30 days of the order for which hearing adequate public notice shall be given. Within 30 days after the adjournment of the hearing, the municipality shall either issue the permit or deny the permit setting forth the reasons therefor. In the event that a permit applied for is denied by the municipality, the applicant may request a hearing before the municipality with reasonable public notice given.

The board shall issue no permit without notifying the municipality in which the proposed alteration is to occur and considering any comments filed within a reasonable period by that municipality.

No permit issued by a municipality may become effective until 30 days subsequent to its issuance, but if approved by the board in less than 30 days then the effective date shall be the date of approval. A copy of the application for the permit and the permit issued by the municipality shall be sent to the board immediately upon its issuance by registered mail. The board shall review that permit and either approve, deny or modify it as it deems necessary. Failure of the board to act within 30 days of the receipt of the permit by the municipality shall constitute its approval and the permit shall be effective as issued.

When winter conditions prevent the board or municipality from evaluating a permit application, the board or municipality, upon notifying the applicant of that fact, may defer action on the application for a reasonable period. The applicant shall not during the period of deferral fill or cause to be filled, dredge or cause to be dredged, drain or cause to be drained or otherwise alter that coastal wetland.

2. **Sand dunes permit.** If the applicant for a sand dunes permit demonstrates to the satisfaction of the board or municipality, as appropriate, that the proposed activity will not unreasonably interfere with existing recreational or wildlife uses; unreasonably interfere with the natural supply or movement of sand within or to the sand dune system; unreasonably increase the erosion hazard to the sand dune system; or cause an unreasonable flood hazard to structures built in, on or over any coastal sand dune or neighboring property, the board or municipality shall grant the permit upon such terms as are necessary to insure that the proposed activity will comply with the foregoing standards.

3. **Single permit.** In the event that a project affects both wetland areas and sand dune areas, the board or municipality, as appropriate, shall grant a single permit upon such terms as are necessary to comply with the foregoing standards.

§ 475. Penalties

A violation is defined as any filing, dredging, draining, depositing, altering, erecting or removal of materials which takes place in coastal wetlands or coastal sand dunes contrary to the provisions of a valid permit or without a permit having been issued, and without regard to whether these physical acts were witnessed as they were being carried out or whether the action was willfully undertaken to avoid the intent of this subchapter or without knowledge of this subchapter undertaken. Any such filling, dredging, draining, depositing, altering or removal of materials shall be prima facie evidence that it was done or caused to be done by the owner of the coastal wetlands or coastal sand dunes.

§ 476. Enforcement

Inland fish and game wardens, coastal wardens and other law enforcement officers enumerated in Title 12, section 7055 shall enforce this subchapter.

§ 478. Exemptions

The Board of Environmental Protection may by rule or regulation exempt from this subchapter certain activities including, but not limited to, repairs and maintenance of existing structures or waive such procedural requirements as it deems not inconsistent with the purposes of this subchapter. Nothing in this subchapter shall prohibit the minor repair of existing permanent structures which would require less than a total of one cubic yard of material to be filled, deposited, dredged, moved or removed in any coastal wetland or normal maintenance or repair of presently existing ways, roads or railroad beds nor maintenance and repair of installations and facilities of any utility as defined in Title 23, section 255, abutting or crossing said coastal wetlands, provided no watercourse is substantially altered.

*Administered by: Maine Department of Environmental Protection, Bureau of Land Quality Control, State House Station #17, Augusta, Maine 04333. Telephone (207) 289-2111.